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Technology Assessment and Evaluation Branch
Emission Control Technology Division
Mobile Source Air Pollution Control
Environmental Protection Agency

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The U.S. EPA determines emission level of automobiles through testing to estimate vehicle fleet emissions which are often critical to local air quality planning. It is important therefore, that the test procedure for determining vehicle emissions simulates, as accurately as possible, the conditions existing in areas where vehicle emissions are of major concern. The purpose of this study was to generate preliminary data on the effect of the following test variables on CO emission test results: (1) Alternate soak times prior to the '75 Federal Test Procedure (2) Alternate soak temperature prior to the '75 Federal Test Procedure (3) Alternate driving cycle. The directionality of these effects was known from previous studies. In question was the relative magnitude of each on emission levels of recent production cars as well as "pre-emission control" cars.

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Background

The Environmental Protection Agency determines emission levels of automobiles through testing to estimate vehicle fleet emissions which are often critical to local air quality planning. It is important, therefore, that the test procedure for determining vehicle emissions simulates, as accurately as possible, the conditions existing in areas where vehicle emissions are of major concern. The purpose of this study was to generate preliminary data on the effect of the following test variables on CO emission test results:

1. Alternate soak times prior to the '75 Federal Test Procedure.

2. Alternate soak temperature prior to the '75 Federal Test Procedure.

3. Alternate driving cycle.

The directionality of these effects was known from previous studies. In question was the relative magnitude of each on emission levels of recent production cars as well as "pre-emission control" cars.

Conclusions

1) With soak temperatures of 10-25°F CO exhaust emissions were substantially increased over identical tests following 68°-80°F soaks. '75 FTP Bag 1 CO emissions for the 1976 model cars tested increased by factors ranging from 3 to 7. During the first 125 seconds of the '75 FTP, CO levels as high as 350 grams/mile were emitted by these vehicles.

2) The extreme CO emission levels observed at start up following an overnight soak decay rapidly to fully warmed emission levels within approximately 5 minutes after start up. The decay was more rapid for the '75 FTP than for the NYC cycle (a driving cycle representing New York City traffic) because the FTP is a higher speed, more strenuous cycle.

3) The type of emission control system on the vehicle had a strong impact on both the level of CO emissions and their distribution over the driving cycle. For example, while the '76 Granada and '76 CVCC Civic were the two lowest CO emitters, Bag 1 CO emissions represented 90% of the total '75 FTP CO value for the Granada versus 28% for the Civic.

4) Comparing the emissions performance of '76 models to the "pre-emission control cars", the results show that emissions controls have not reduced CO emissions for low temperature cold starts as much as for the normal FTP temperature cold start conditions.

5) As all of the cold start effects on emissions decay within the Bag 1 sampling period, Bags 2 and 3 emissions are virtually independent of soak time or temperature. Thus, Bag 1 CO emissions as a percent of the '75 FTP composite value increase as the soak temperature is lowered and/or the soak time increased.

6) On a grams/mile basis, CO emission levels over the NYC cycle were 2 to 3 times those of Bag 1 of the '75 FTP for a given vehicle and soak temperature.

7) On a grams/minute basis, the CO emission levels of Bag 1 of the '75 FTP were within a factor of 2 of the NYC levels for any given vehicle and soak temperature. On the same grams/minute basis, decreasing the soak temperature from 77°F to 10-25°F increased Bag 1 and NYC CO emissions by factors ranging from 1.5 to 75. This suggests that for ambient air modeling of cold climate regions, the ambient temperature can be more influential than the driving cycle.

8) The effect of soak time is strongly soak temperature dependent. For example, CO emissions following a two-hour soak at 10-25°F are about the same as those following an overnight soak at approximately 77°F. This suggests that a vehicle in cold weather can have multiple "cold starts" in an eight hour period if soak times are two hours or more.

9) A relationship between CO emissions and engine coolant temperature may exist for a given control technology and driving cycle. Since engine coolant temperature could be adequately modelled knowing ambient temperature, soak time, possibly wind speed, and some basic vehicle information, the engine coolant temperature may be a useful parameter for predicting vehicle emissions over a wide range of soak times and temperatures.

10) The use of winter grade fuels instead of the Indolene test fuel for '75 FTPs following soaks at 10-25°F reduced HC emissions during the first 125 seconds by approximately 50% but had no appreciable effect on CO emissions.

11) The temperature and soak time effects on HC emissions were largely similar to those on CO.

12) The temperature and soak time effects on NOx emissions and fuel economy while detectable were not extreme. Of equal or greater influence was the differences in the driving pattern between different parts of a driving cycle.

Test Procedure

Each of the five vehicles examined was tested as follows:

Exhaust emissions generated on a chassis dynamometer were collected and measured by constant volume sampling with multiple sample bags. The LA-4 and New York City S-8 (NYC) driving cycles were each divided into seven sampling periods or modes as shown in Table 1. Also shown in Table 1 are the total time, total distance, average speed, maximum speed, and percent of time at idle for each mode and the cycle as a whole.

Table 1
Mode Number

LA-4	1	2	3	4	5	6	7	Whole Cycle
Begin time (sec)	0	125	333	429	505	766	1023	0
End time (sec)	125	333	429	505	766	1023	1372	1372
Total time (sec)	125	208	96	76	261	518	349	1372
Distance (mi)	.68	1.95	.51	.45	.96	1.76	1.19	7.50
Average Speed(mph)	19.6	34.1	19.3	21.4	13.3	12.1	12.2	19.7
Max. Speed (mph)	32.4	56.7	36.5	36.1	28.6	34.3	29.1	56.7
% of time @ idle*	16.0	18.8	20.8	25.0	25.3	1.0	28.4	19.5

NYC	1	2	3	4	5	6	7	Whole Cycle
Begin time (sec)	0	85	143	195	274	344	446	0
End time (sec)	85	143	195	274	344	446	598	598
Total time (sec)	85	58	52	79	70	102	152	598
Distance (mi)	.09	.10	.20	.25	.19	.13	.22	1.18
Ave. Speed (mph)	3.7	6.3	13.9	11.2	9.8	4.6	5.3	7.1
Max. Speed (mph)	22.9	17.4	25.2	26.4	22.4	15.8	27.7	27.7
% of time @ idle*	60.0	27.6	13.5	22.8	20.0	52.9	60.5	42.1

* Speed less than 1.0 mph.

Speed time traces of the two cycles showing the sample switching point and other pertinent information are shown in Appendix A. In preparation for the test the vehicles were pre-conditioned by driving on the dynamometer until fully warmed and ending with the first 505 seconds of the LA-4 driving cycle.

Following this pre-conditioning the vehicles were soaked for one of the following soak times:

Overnight (16-20 hours)
4 hours
2 hours
1 hour

During the soak periods the vehicles were either parked in the controlled ambient soak bay (72°-80°) or outdoors with ambient temperatures of 10°-25°F. In all cases the test cell was maintained at 68°-80°F. It would have been more desireable to run the dynamometer test portion at the soak temperature but the available dynamometer test cells did not have low operating temperature capability. Tests were also conducted with the vehicles fully warmed following a 10 minute soak period at test cell temperature.

During the testing, air and/or engine temperatures were monitored in the following locations.

1. Ambient air (in front of radiator, shielded from the radiator).
2. Inside the air cleaner filter element.
3. In front of the air cleaner (chosen to represent underhood temperature).
4. Fuel just before entering carburetor.
5. Engine coolant in the head or block.
6. Engine oil sump.
7. Transmission fluid sump.

Diluted exhaust and background bags were analyzed for HC, CO, CO_2, and NOx using flame ionization, non-dispersive infrared (NDIR), NDIR, and chemiluminescent analyses respectively.

Test Vehicles

The five test vehicles consisted of the following:

Vehicle	Engine		Trans.	Emission Control
1. 1970 Plymouth Valiant	225 CID	I-6	Auto.	Engine Mod.
2. 1970 Chevrolet Impala	350 CID	V-8	Auto.	Engine Mod.
3. 1976 Chevrolet Impala	350 CID	V-8	Auto.	Catalyst, EGR
4. 1976 Ford Granada	250 CID	I-6	Auto.	Catalyst, Air, EGR
5. 1976 Honda CVCC Civic	91 CID	I-4	4 speed Manual	Pre-chamber Stratified Charge

Detailed specification of these vehicles are given in Appendix B. The first two vehicles were chosen as representative of "uncontrolled" vehicles. Vehicle 3 was selected as representative of pelleted catalyst control technology without secondary air. Vehicle 4 represents monolith catalyst technology with secondary air injection (air pump). Vehicle 5 represents overall lean stratified charge technology.

Results and Discussion

Figure 1 displays CO emissions of the 1970 Impala mode by mode over the LA-4 and NYC cycles. Both cycles were begun with an engine start in the fully warmed condition. As the coordinates of this figure are grams/mile CO and cycle distance, the area under the bar graphs is proportional to grams of CO. Also shown are straight lines connecting the emission levels plotted at the distance corresponding to the end of the mode represented. The area under these sloping lines roughly approximates the total grams of CO emissions. This method of presenting the data will be used in subsequent plots because it facilitates multiple plotting on a single figure. It can be seen that even on a fully warmed vehicle the type of driving cycle has a significant effect on the emission levels. The NYC cycle, designed to simulate driving patterns in the heavily congested New York City area, produced overall CO grams/mile emissions three times that of the LA-4 cycle for this "pre-control" car. A major reason for this is the much higher percentage of idle in the NYC (See Table 1). Idle operation, of course, adds to the emissions but not the distance traveled.

1. Cold Start from Approximately 77°F.

Figure 2 is similar to Figure 1 with the addition of the CO emissions of the same vehicle for the two cycles when it was "cold started" after soaking overnight at approximately 77°F. Of interest here is the much higher CO emissions levels produced during the "cold start" and the distance required for these "cold start" emission levels to decay to those of the fully warmed condition. For the 1970 Impala the mode 1 CO emissions for the cold start are a factor of 10 greater than the hot start for both the LA-4 and NYC cycles.

Figure 3 shows the CO emissions of the five vehicles mode by mode for the standard '75 FTP. Figure 4 displays the same variables for the NYC cycle begun with a cold start after an overnight soak at approximately 77°F (note the difference in the CO emissions scaling between the two graphs).

These two figures show the characteristics of all vehicles as being relatively high cold start emissions that decay to the fully warmed-up level. Fully warmed emission levels were largely achieved after 0.67 miles and 125 seconds for the LA-4 and 0.19 miles and 143 seconds for the NYC cycle. Also evident is the relative performance of the differing control technologies. Appendix C contains similar graphs of the HC and NOx emissions and fuel economy of the five vehicles under the same test conditions.

2. Effect of Varying Soak Times at Approximately 77°F

Figures 5 and 6 show the effect of varying soak times on the mode CO emissions over the LA-4 and NYC cycles respectively for the '70 Impala. Comparable graphs for the other vehicles are given in Figures 7-14. In nearly all cars the biggest increase in Mode 1 CO emission occurred between the overnight and 4 hours soak times. Much smaller Mode 1 increases in CO emissions occurred between the 4 hour and 2 hour soak times, and the 1 hour soak was often indistinguishable from the fully warmed condition. Appendix D contains similar graphs of the HC and NOx emissions and fuel economy of each of the vehicles with varying soak time at room ambient approximately 77°F.

3. Cold Start from 10-25°F

Figures 15 and 16 show the CO emissions of the five vehicles mode by mode for the '75 FTP and NYC cycles begun with a cold start after an overnight soak at 10-25°F. Again the mode 1 emissions are very high, but the range between vehicles is much narrower. The highest emitter, the '70 Valiant, emitted only 2 to 3 times as much as the lowest emitter the '76 CVCC Civic. For the cold starts from room temperature this range was an order of magnitude larger. This suggests that emission control approaches have not significantly altered the lower temperature cold start emissions. Appendix E contains similar graphs of the HC and NOx emissions and fuel economy of the five vehicles under the same low temperature cold start conditions.

4. Effect of Varying Soak Times at 10-25°F

Figures 17-26 show the effect of varying soak times at temperatures between 10 and 25°F on the mode CO emissions over the LA-4 and NYC cycles for each of the vehicles. The most obvious differences due to the lower soak temperature is the much greater mode 1 emissions. The distance and time required for the overnight soak emissions to decay to those of the fully warmed condition increased to 2.65 miles and 333 seconds for the LA-4 and 0.64 miles and 274 seconds or more for the NYC. Similar graphs of the HC and NOx emissions and fuel economy are in Appendix F.

Note that the LA-4 decay time appears greater than that of the NYC. This is not real but an artifact of the comparitively longer mode 2 of the LA-4. In fact, the vehicles warm up more quickly on the LA-4 cycle and therefore probably reach fully warmed emission levels sooner. Figures 27, 28, 29, and 30 show the time temperature traces of the various vehicle locations monitored during the testing of the vehicles. These traces, for the '70 Valiant, are typical of all the cars. It is clear that for comparable soak temperatures nearly all temperatures monitored achieve stabilized values quicker over the LA-4 than on the NYC. This is to be expected as the LA-4, particularly the first 505 seconds (Bag 1), is much more strenuous than the NYC in that the LA-4 has much higher maximum and average speeds and less idle time.

It is also clear from Figures 27-30 that lower soak temperatures increase temperature stabilization times for both cycles, particularly for the NYC.

5. Tabular Review of All CO Data

Table 2 gives the CO emissions of the five vehicles over the '75 FTP and the NYC in the fully warmed condition and with overnight soaks at room temperature and outside ambient. Of note here is that Bag 2 emissions of the '75 FTP are nearly independent of the starting temperature of the vehicle, reflecting the fact that even for the starts after outside ambient soaks the cold emissions decayed to the fully warmed emissions well within Bag 1. Note also the wide range of emission levels exhibited by the various control technologies. For example, the near zero bag 2 emissions of the monolith car with secondary air versus those of the other catalyst car or the stratified charge car.

The obvious differences in the CO grams/mile emissions between the '75 FTP and the NYC deserve further examination. First the NYC, being only 598 seconds long, more closely matches the duration of Bag 1 of the '75 FTP, which is 505 seconds. However, only 20.5% of the Bag 1 grams/mile emissions go into making up the composite '75 FTP grams/mile emissions because of the 0.43 weighting factor applied to the cold start. Thus, the '75 FTP reflects emissions levels 79.5% of which (coming from Bags 2 and 3) are almost independent of the soak condition. A more reasonable comparison is between Bag 1 and the NYC. On a grams/mile basis, the NYC is still considerably larger because of the much shorter distance traveled over the NYC (1.18 vs. 3.59 miles). Table 3 compares Bag 1 and NYC on a grams/minute basis and here the agreement for a given vehicle and soak condition is much better. Thus it appears that despite the gross differences between these two driving cycles the resulting differences in grams/minute CO emissions are small; in most cases within a factor of 2. By contrast, the effect of engine temperature, particularly for the '76 vehicles, produced CO emission levels that differ by factors ranging from 1.5 to 75. This suggests that for ambient air modeling of northern cities, the ambient temperature can be more influential than the driving cycle.

Tables 4, 5, 6, 7, and 8 give the '75 FTP CO emissions of each of the five vehicles for the varying soak times at both soak temperature ranges. The individual Bag emissions and their percentage contributions to the '75 FTP are also given. With the exception of the '70 Valiant (which may have had a sticking choke), Bag 2 emissions were largely independent of soak time and temperature. Bag 3 emissions are artificially identical because only one hot 505 test was conducted for a given soak temperature. Of major interest is the Bag 1 emissions which show that a 2 hour soak at 10-25°F produces CO levels close to those of an overnight soak at approximately 77°F. For all vehicles a 4 hour soak at 10-25°F results in considerably higher Bag 1 CO emissions than those of the overnight soak at approximately 77°F. Thus in cold weather, vehicles could have multiple "cold starts" in a work day if soak times were 2 hours or longer.

Tables 9 and 10 give the CO mode emissions of Bag 1 and their percent of total Bag 1 emissions for the five vehicles following overnight soaks at the two temperature ranges. For both soak temperatures, nearly all the vehicles had emitted 50% or more of their Bag 1 emissions by the end of mode 1 and 90% or more by the end of mode 2. This means that for a Bag 1 type driving cycle, the bulk of the cold start emissions will be emitted within 2.6 miles of the start up point.

6. CO Emissions vs. Engine Temperature

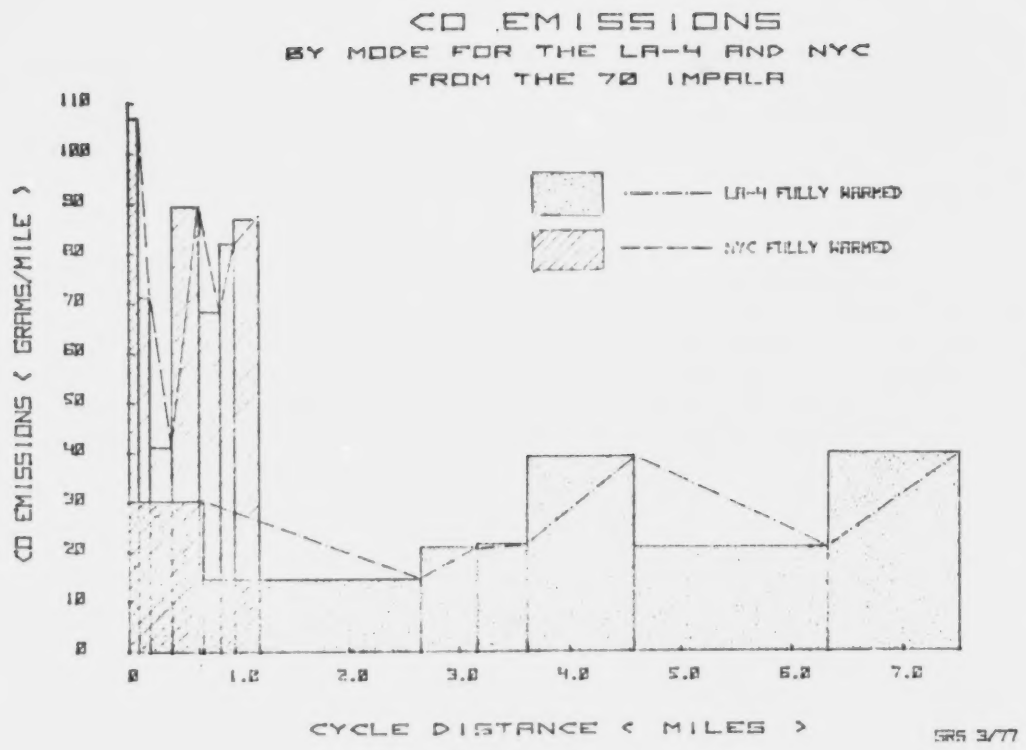
In an attempt to correlate emissions with engine temperature, the CO emissions were plotted against temperature of the engine coolant immediately prior to engine start up following the varying soak times at both soak temperature ranges. Figures 31 and 32 are such plots of the LA-4 Bag 1 and entire NYC cycle CO emissions respectively. The available number of points was inadequate to accurately define the curves for each vehicle, but in both CO emissions vs. coolant temperature figures there appeared curves with steeply decreasing emissions in the temperature range of 25-100°F. This indicates that an engine temperature prior to engine starting is a good predictor of vehicle emissions with a given driving cycle and emission control technology. The advantage of this relationship is that it enables emission levels determined at a specific test condition to be reasonably extrapolated to other test conditions. Figure 33 is the temperature versus soak time plot of the engine head coolant of the vehicles at the two different soak conditions. This graph suggests that a relatively simple heat transfer model could approximate these curves. Thus with just say engine mass, possibly wind velocity and surface area factors, ambient temperature and soak time as inputs the engine coolant temperature could be predicted. This information via the emissions versus engine coolant temperature curves could approximate emissions under a wide variety of conditions.

Test Fuel Effects

Another factor considered was the volatility of the fuel. Vehicles that experience ambient temperatures in the 10-25°F range normally are fueled with winter grade gasoline. The test fuel used was indolene HO which has a Read Vapor Pressure (RVP) of 8.7-9.2 pounds, compared to a RVP of 10-13 for winter grade gasoline. To evaluate the impact of this difference, the '70 Impala, '76 Impala, and the '76 CVCC Civic were also tested over the LA-4 following an overnight soak at outside ambient (10-25°F) with commercially available winter fuel. Figure 34 shows the CO emissions of these three vehicles over the LA-4 for both fuels. There is no definite trend exhibited and with the possible exception of the CVCC Civic what differences do exist are within normal test-to-test variability. Figure 35 shows HC emissions for the same test conditions. For HC the Mode 1

HC emissions with winter fuel averaged over 50 percent lower than with indolene. From Mode 2 on the HC emissions for the two fuels became indistinguishable. The NOx and fuel economy for the same test conditions are given in Appendix G. Also given in Appendix G are the RVP and distillation specification of the two fuels as measured in our laboratory.

In evaluating the data for cold starts following outside ambient soaks, it must be remembered that the test cell and the air entering the vehicle's air induction system was at 68-80°F. This will undoubtedly have an impact on the warm-up rate or the induction system and probably that of the engine and drive train. It is anticipated that the outside ambient cold start HC and CO emission levels would be higher and decay more slowly if the test cell temperature matched that of the soak condition.



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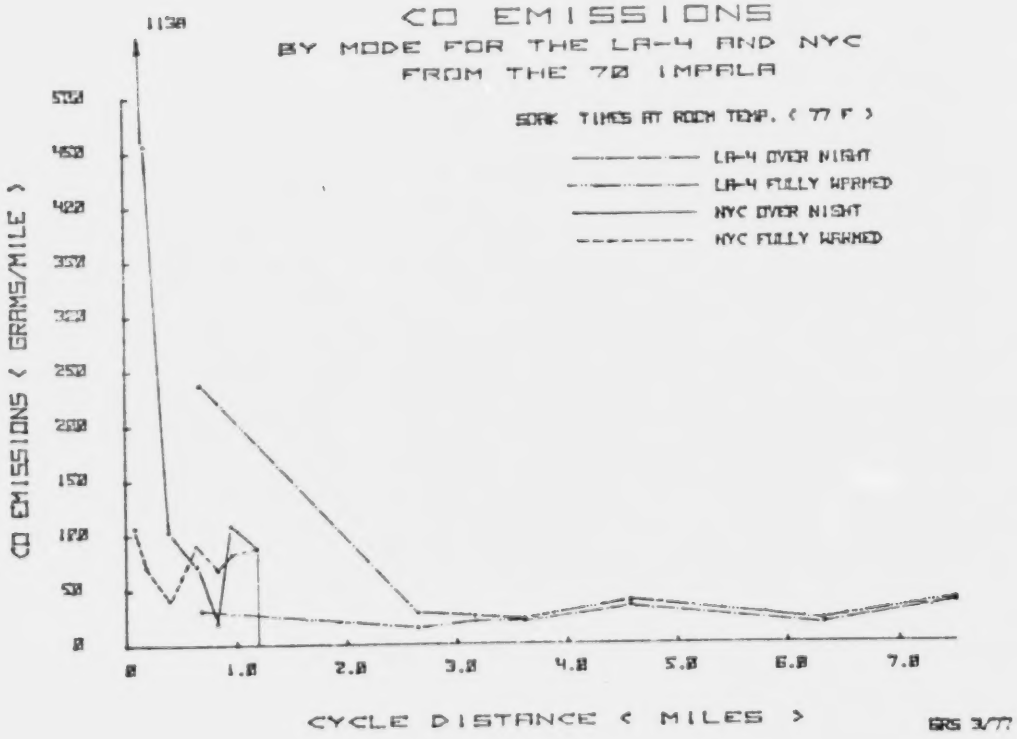

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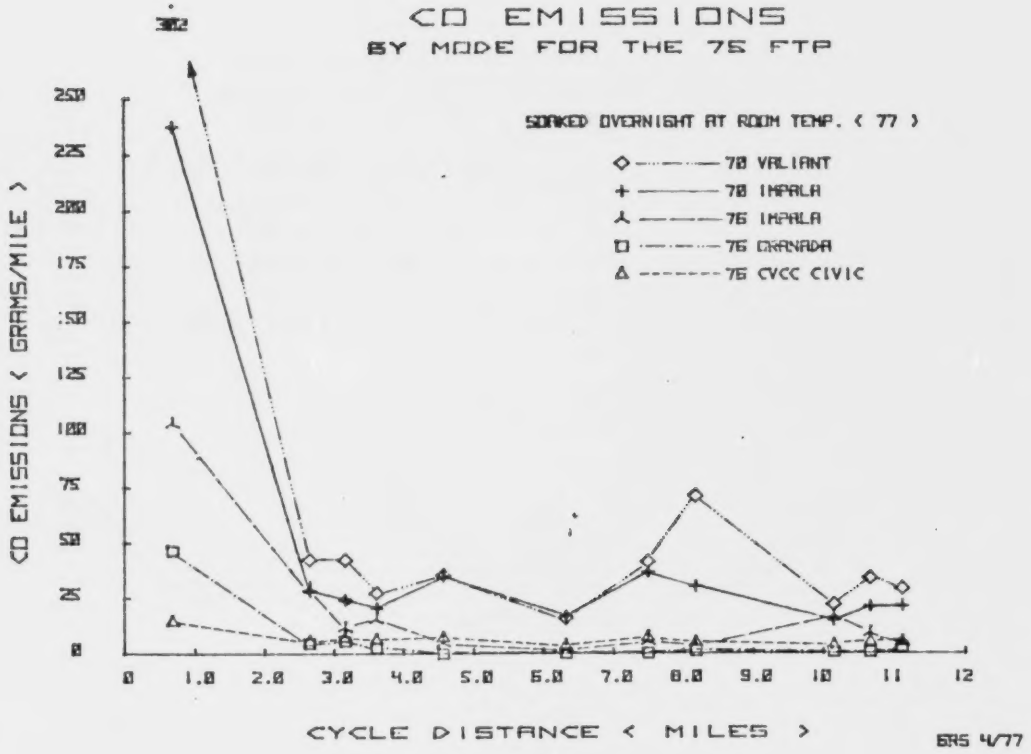

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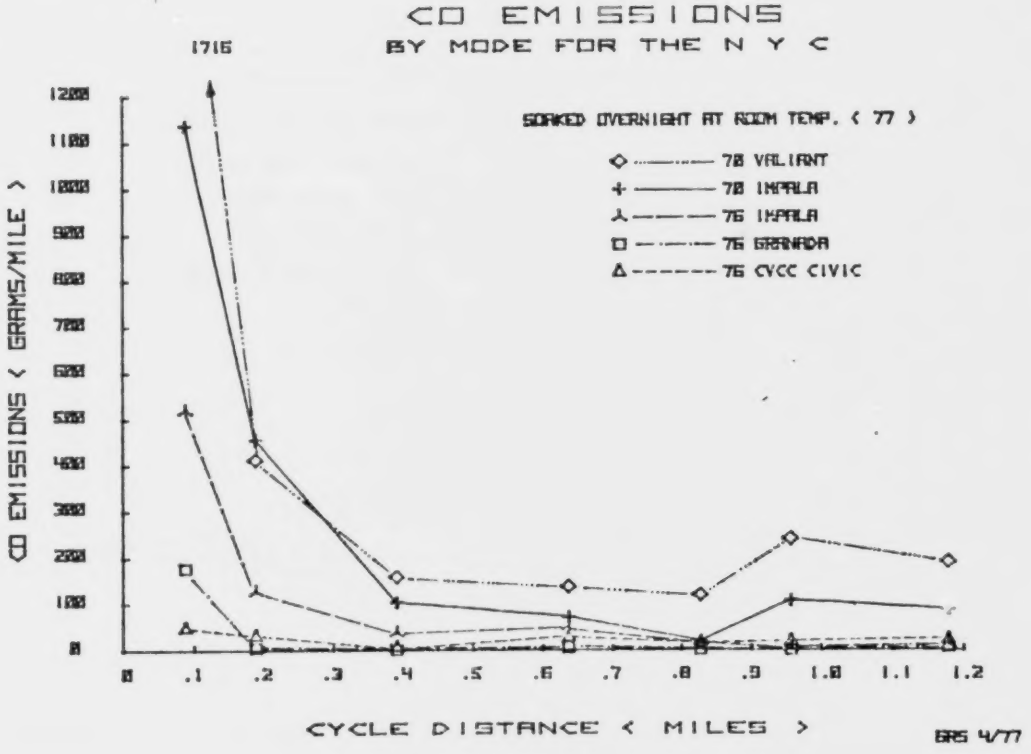

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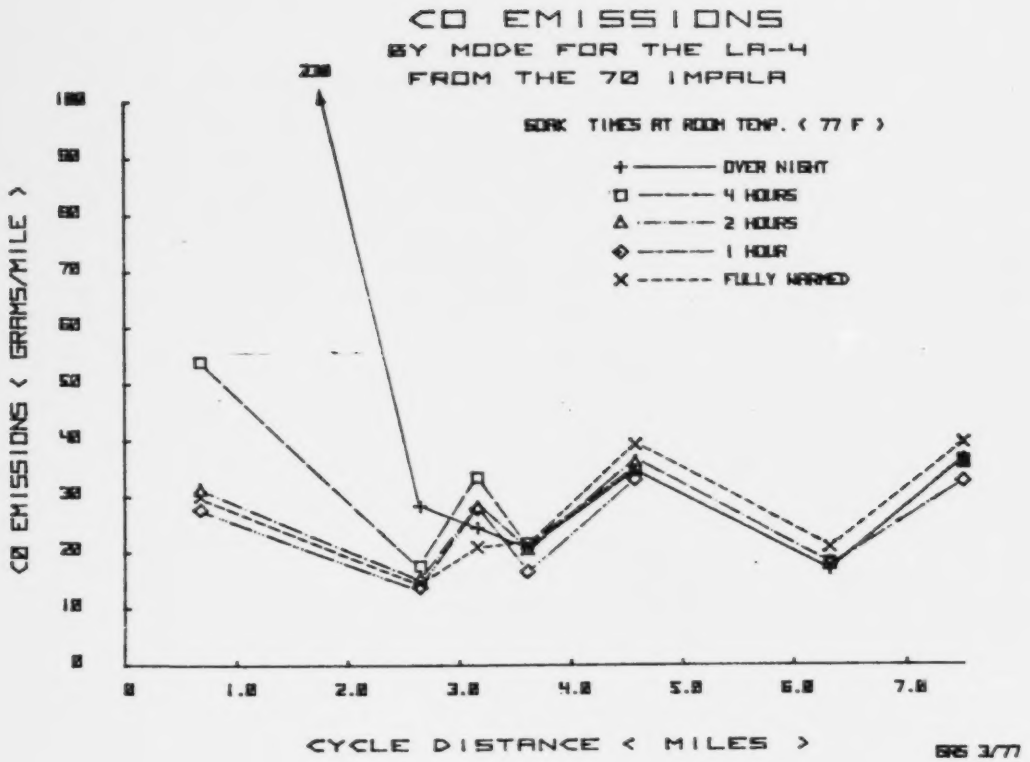

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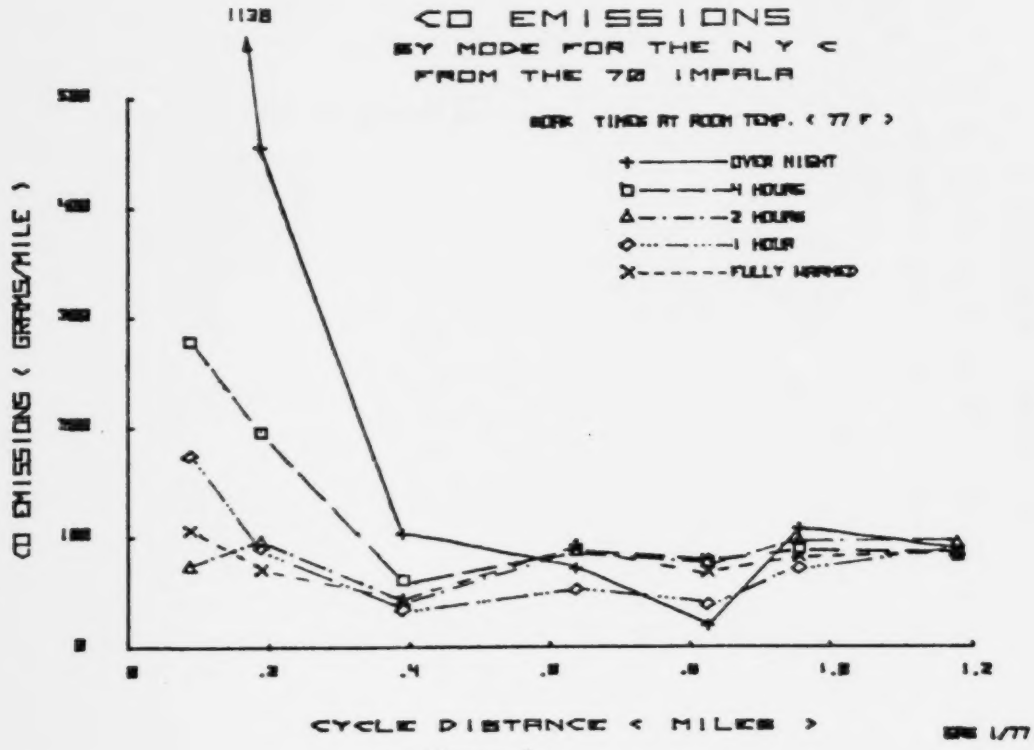

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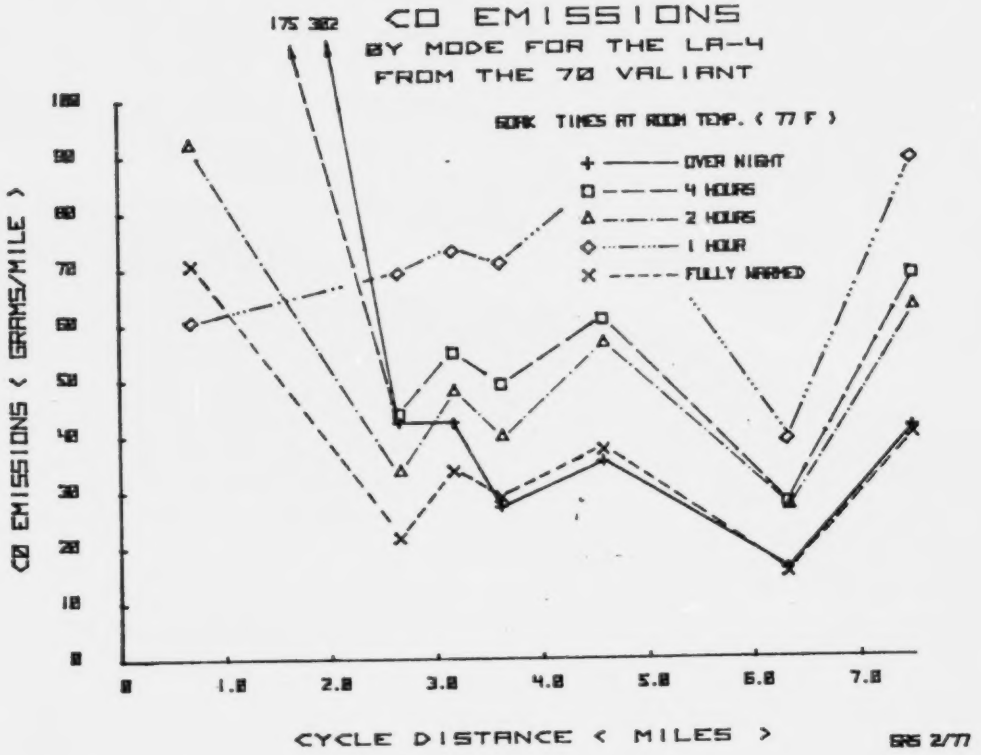

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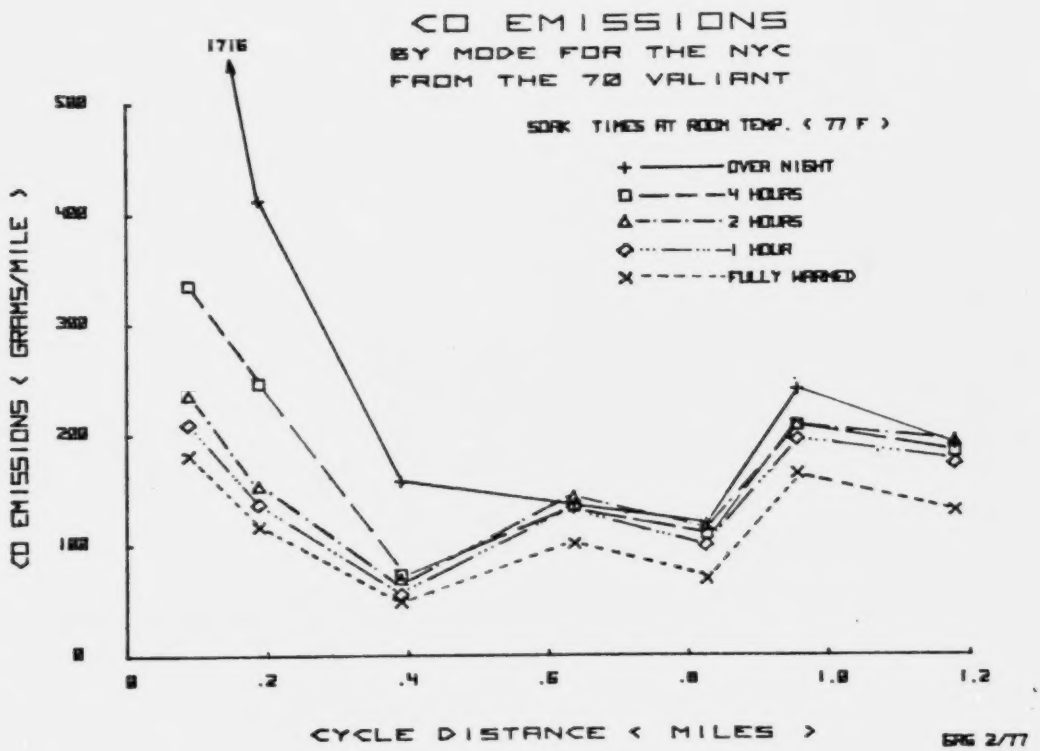

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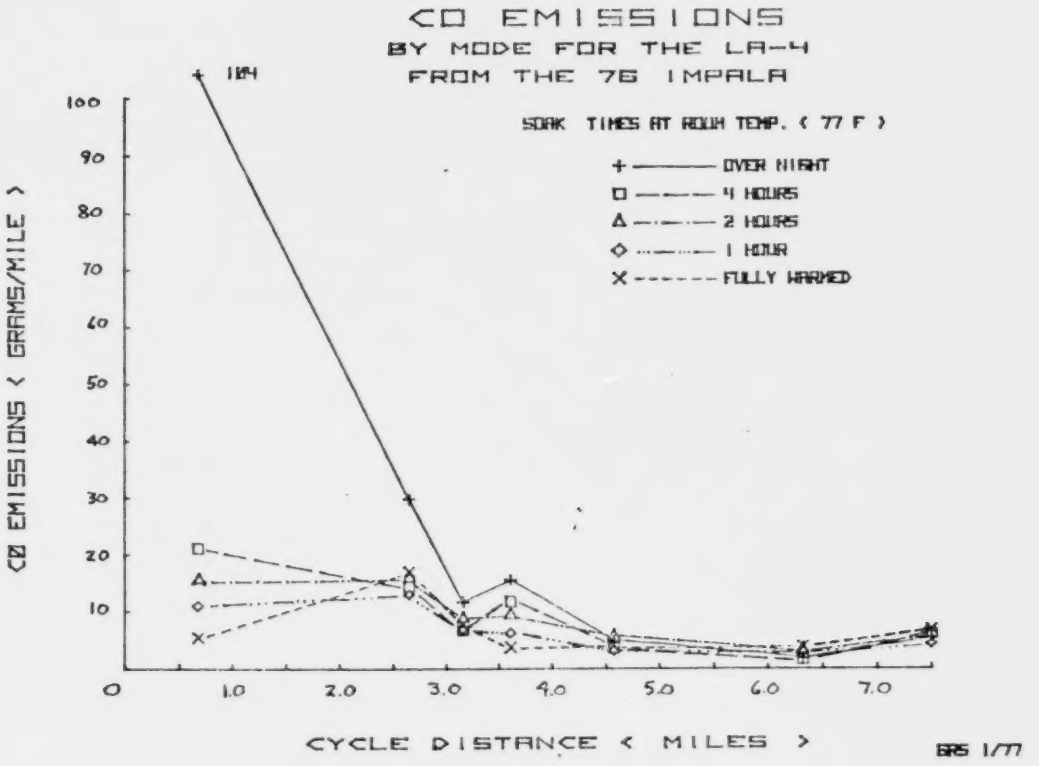

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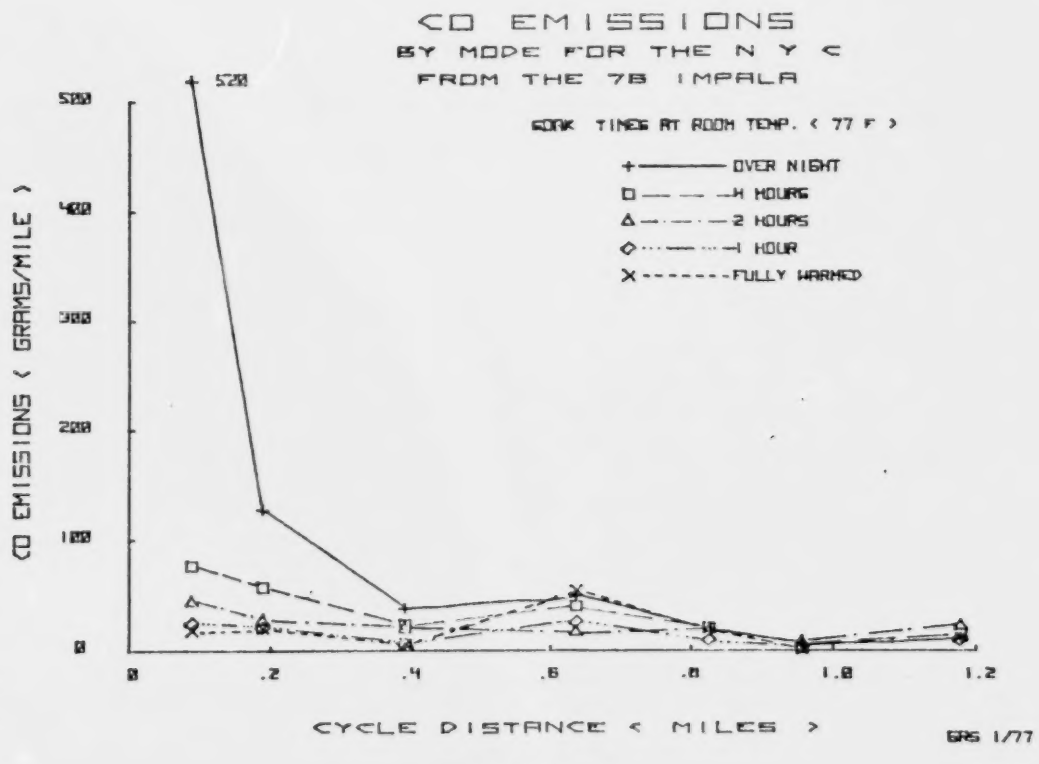

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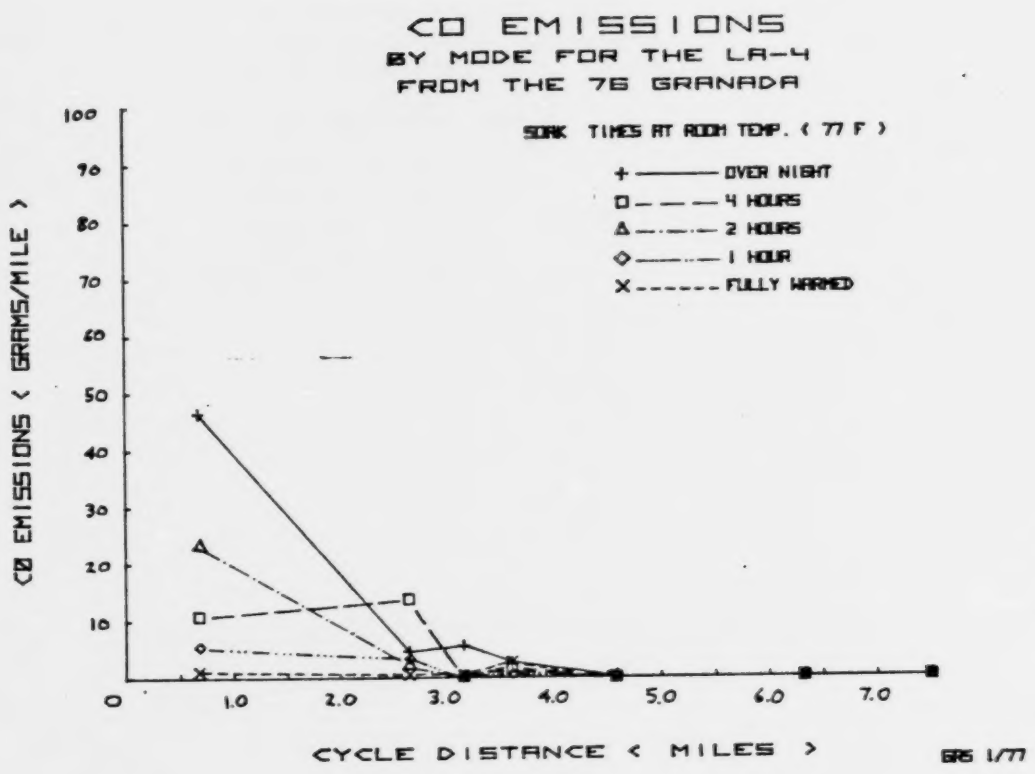

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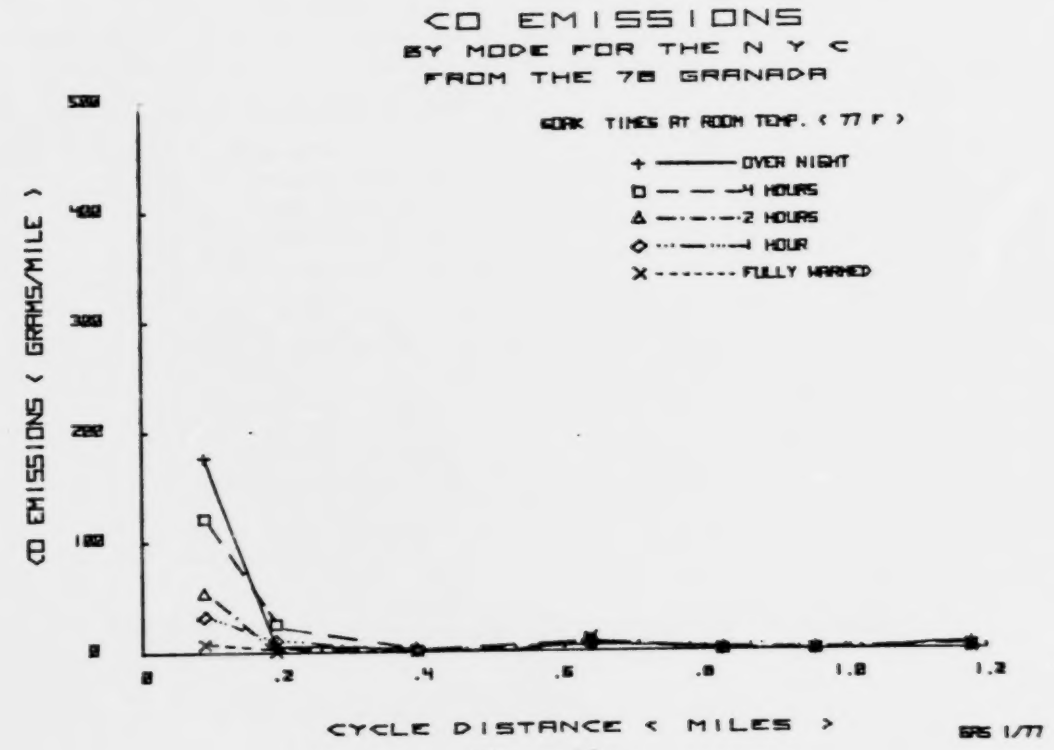

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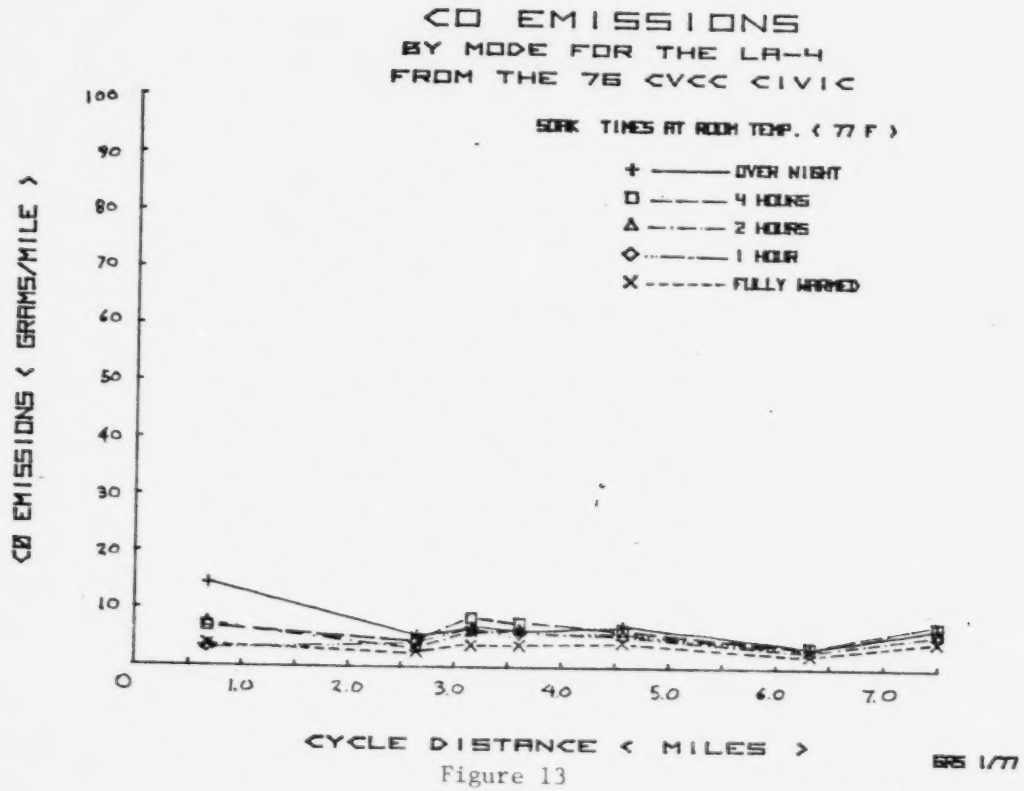

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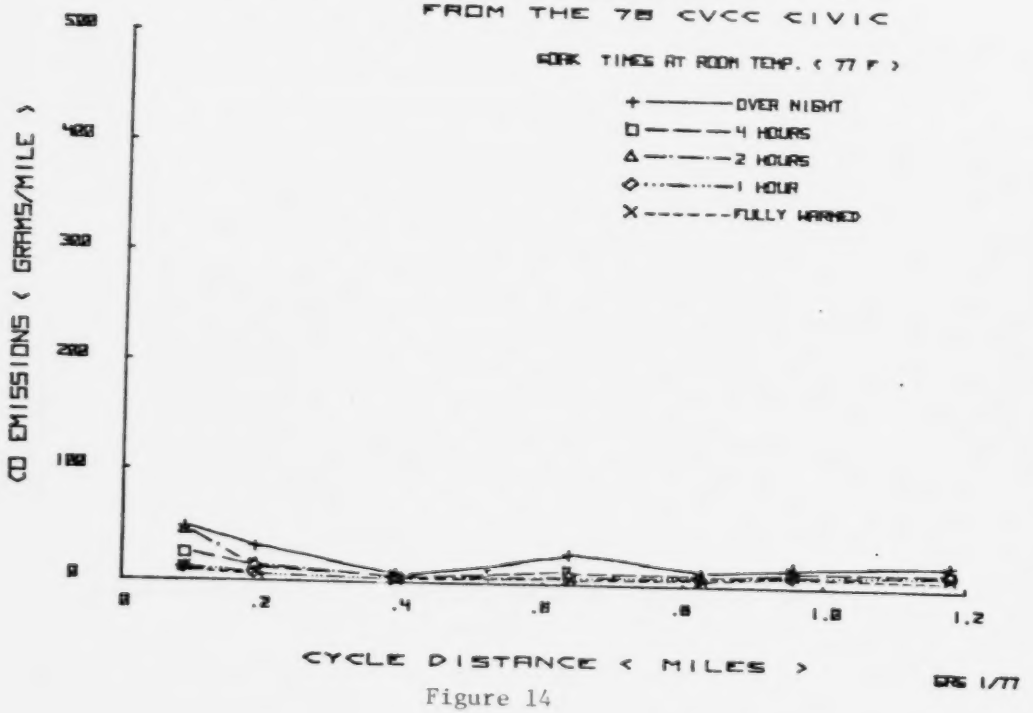

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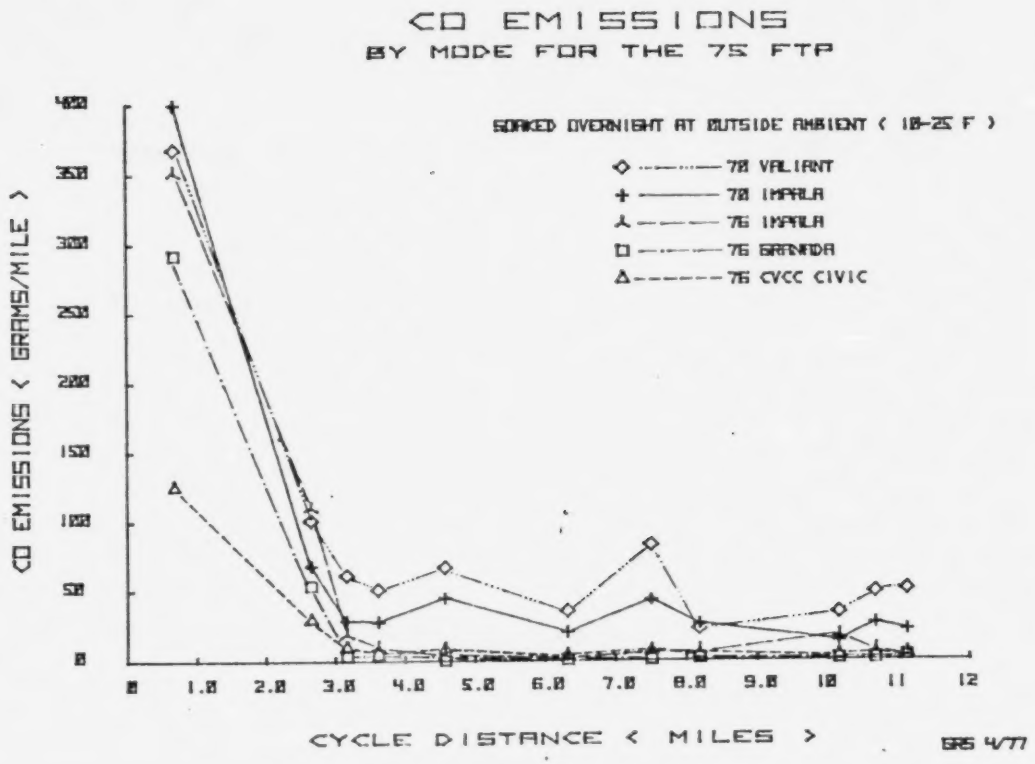

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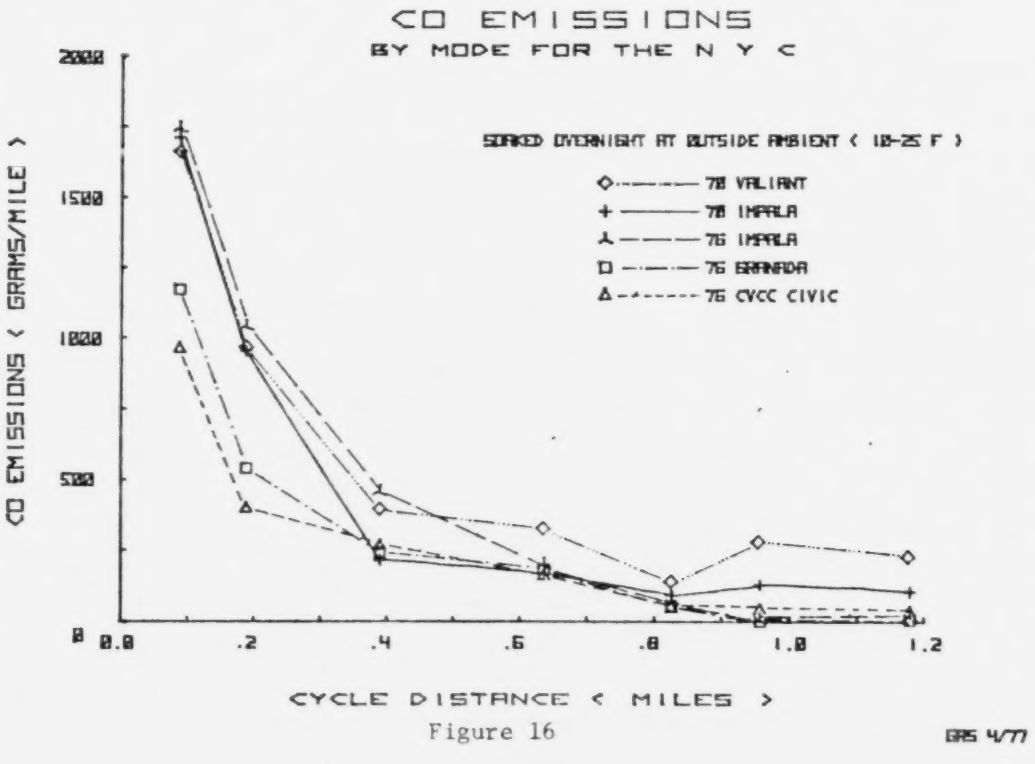


Figure 16

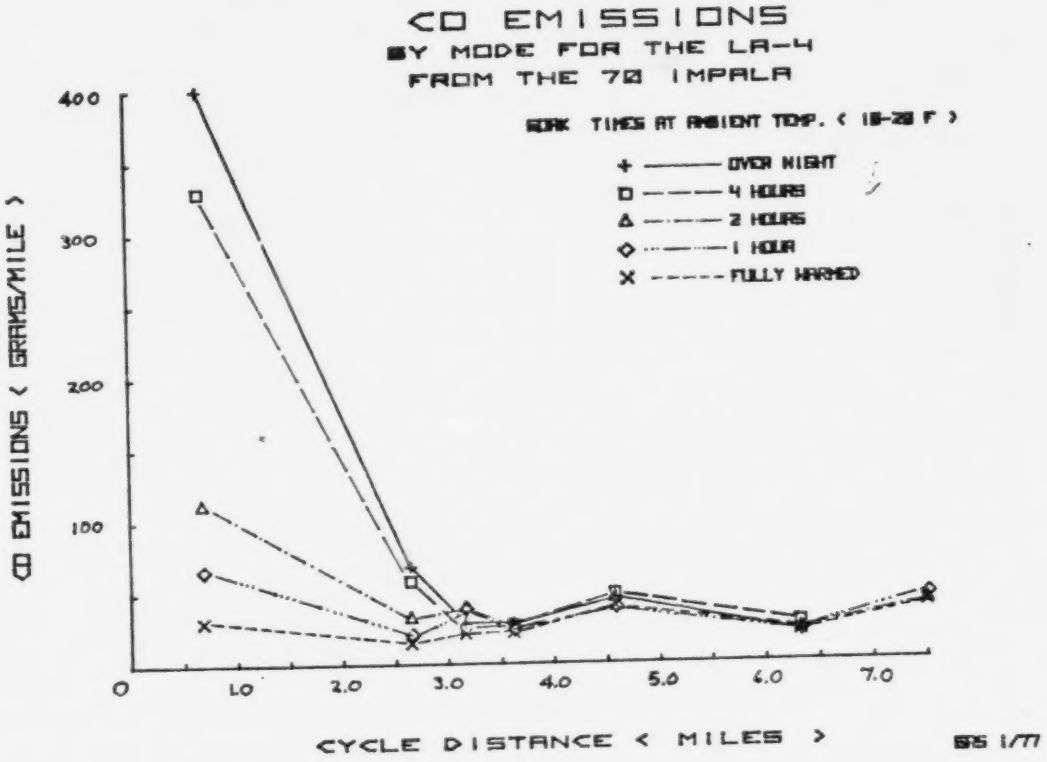


Figure 17

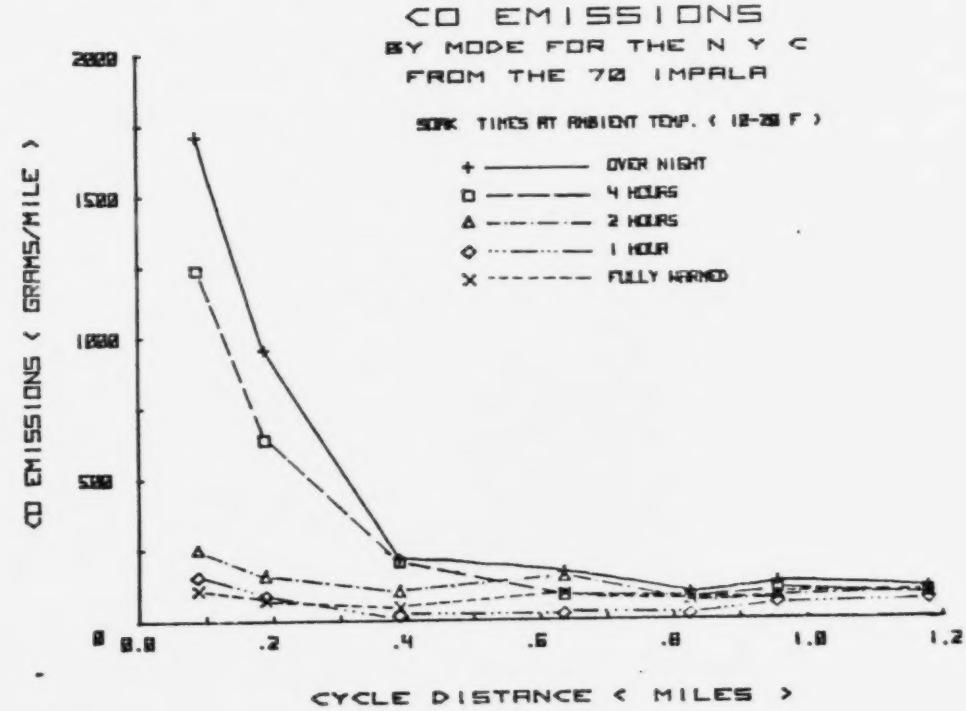
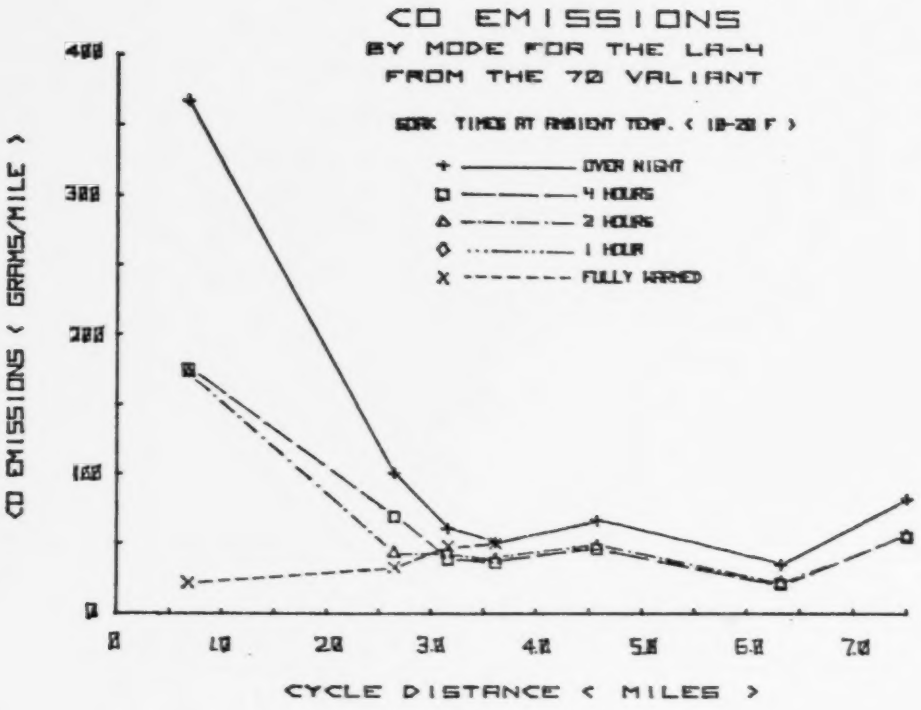


Figure 18



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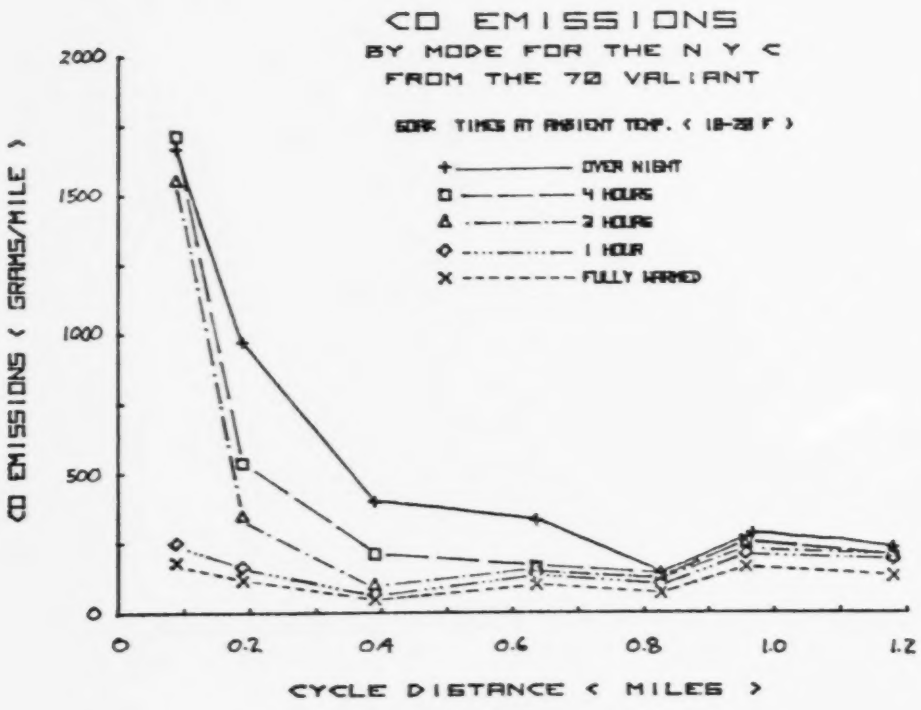

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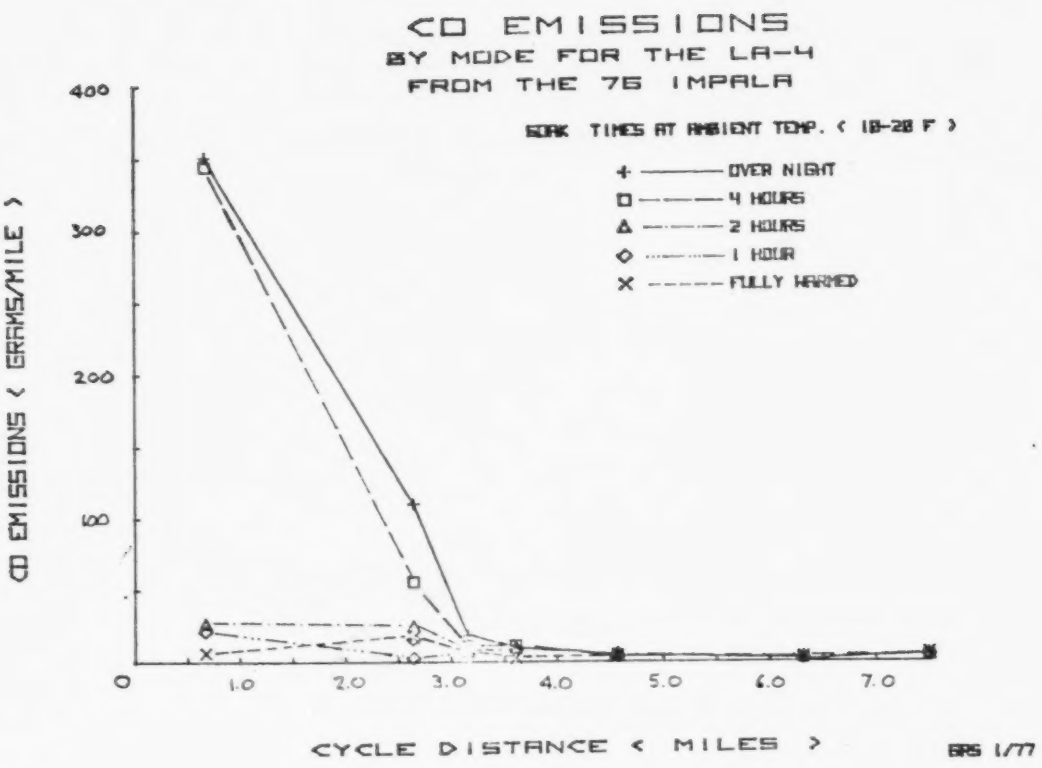

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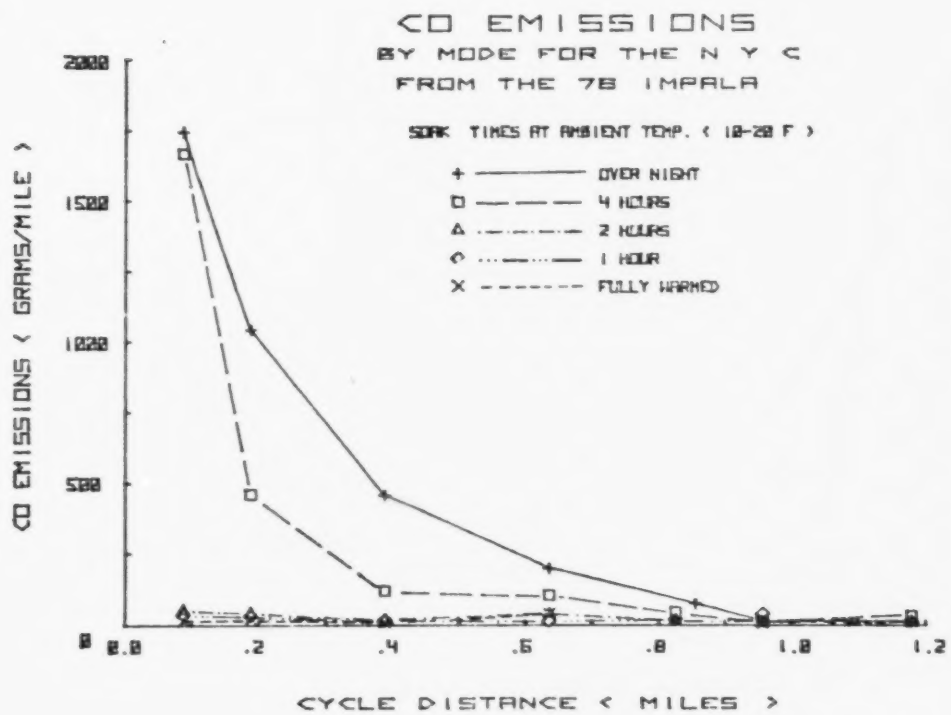
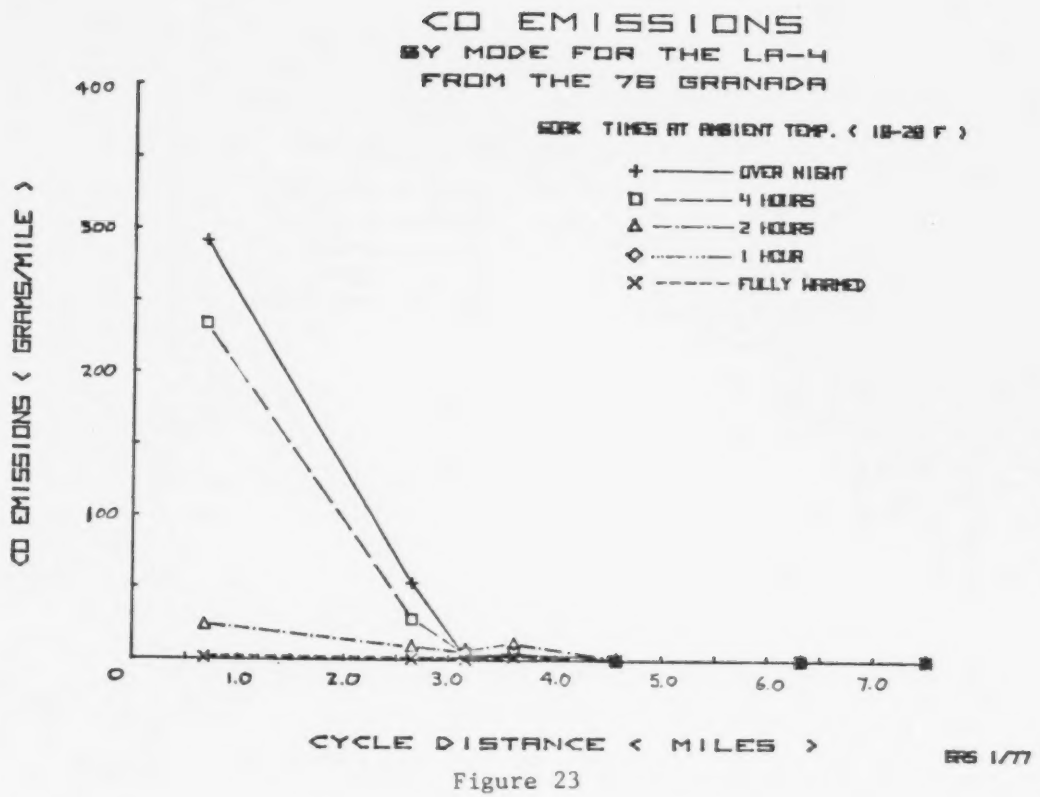


Figure 22

GRS 1/77



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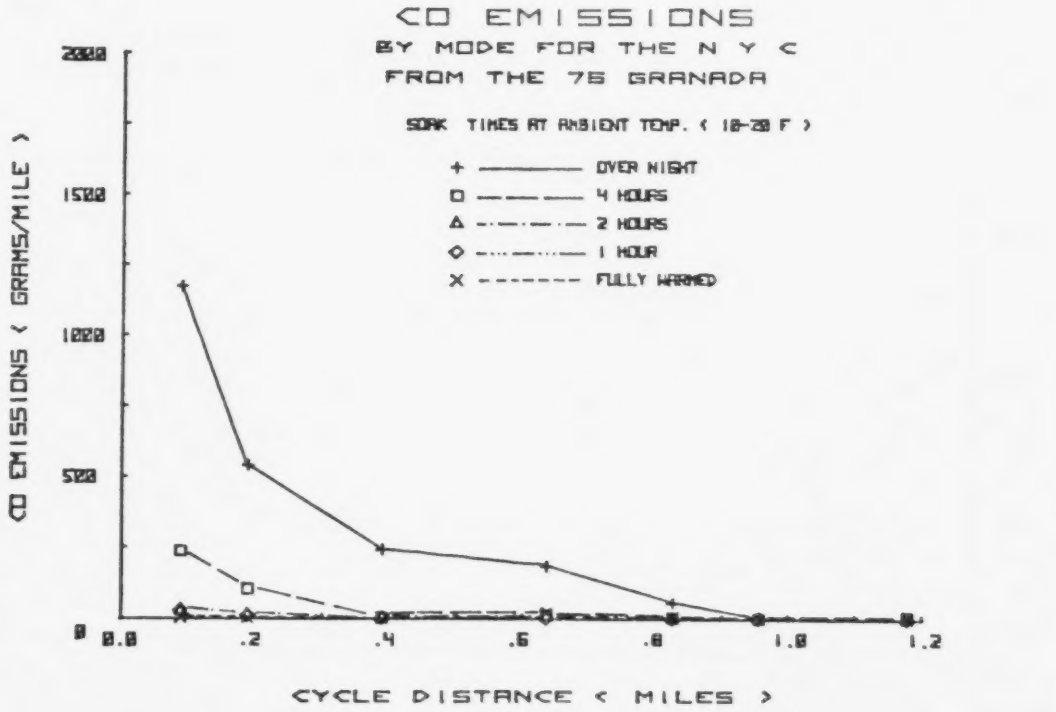

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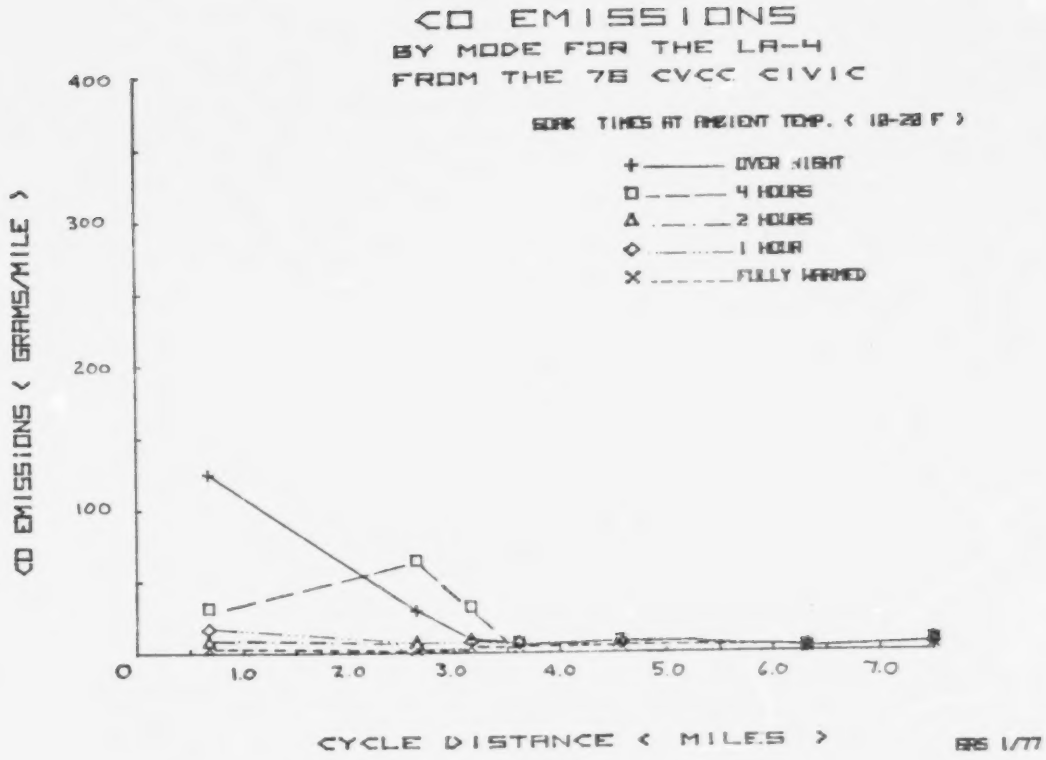

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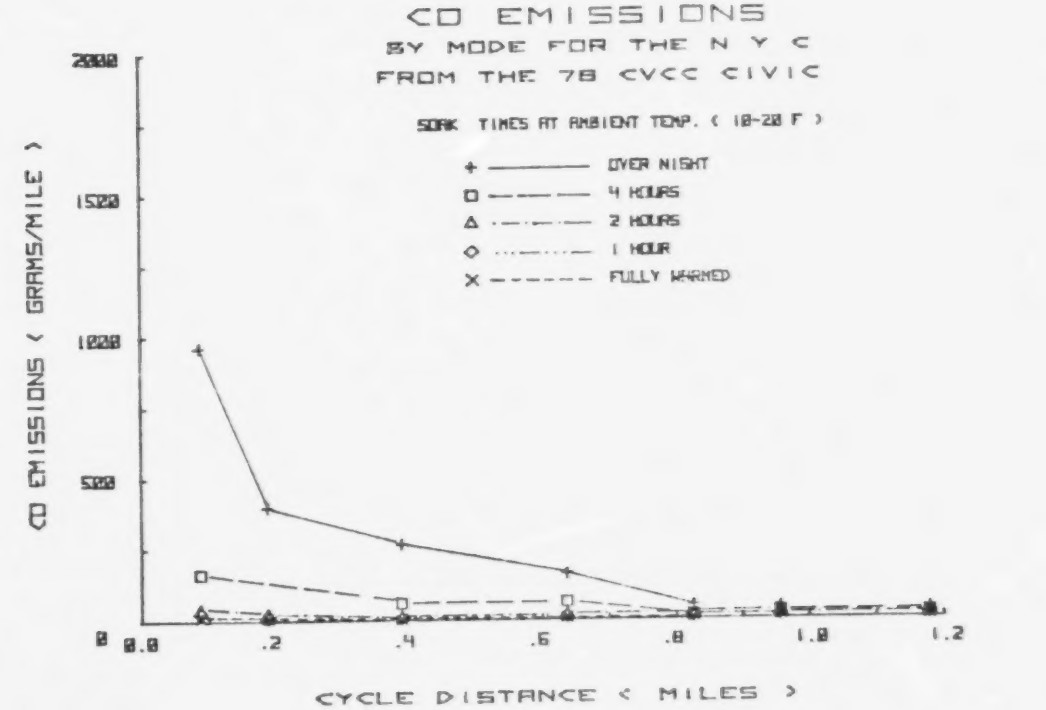

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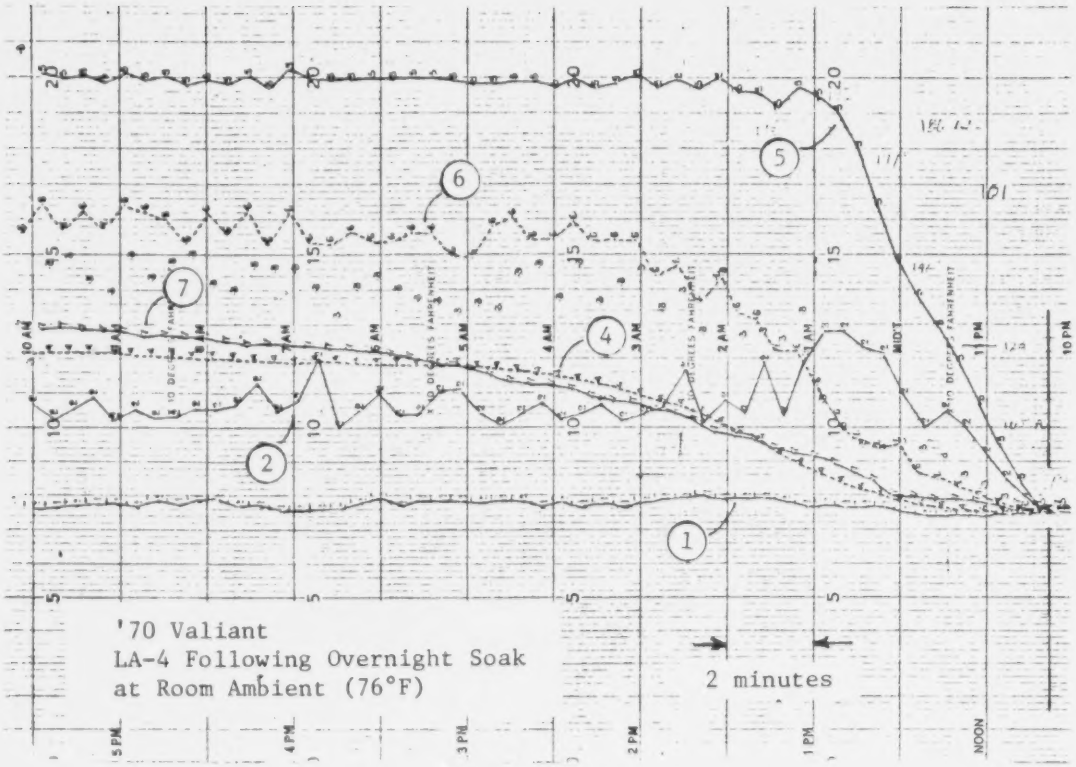

Figure 27

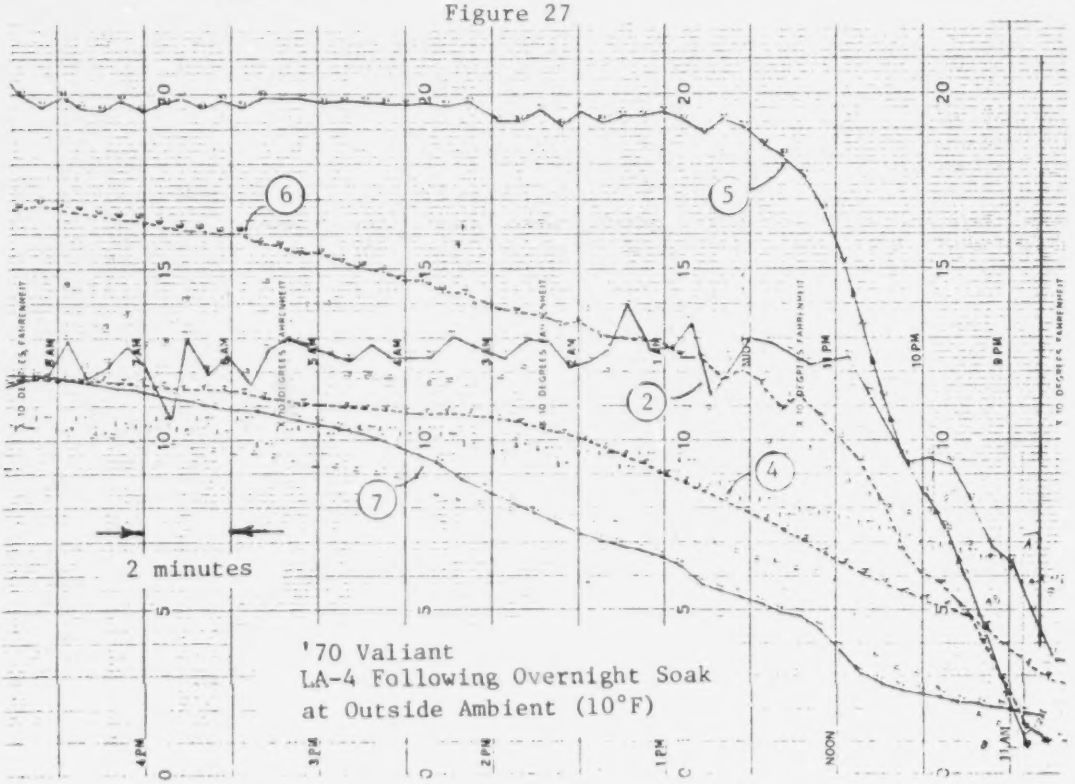

Figure 28

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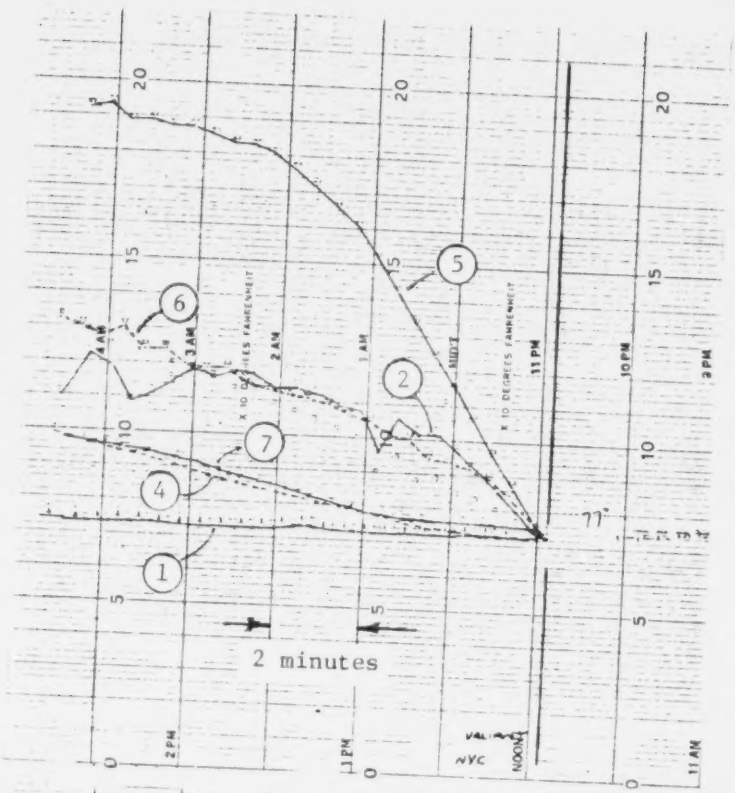

Figure 29
'70 Valiant
NYC Following Overnight
Soak at Room Temp. (73°)

Key for Figures 27, 28
29 and 30
(1) Ambient air
(2) Air entering carburetor
(4) Fuel entering carburetor
(5) Engine coolant
(6) Engine oil sump
(7) Transmission fluid sump

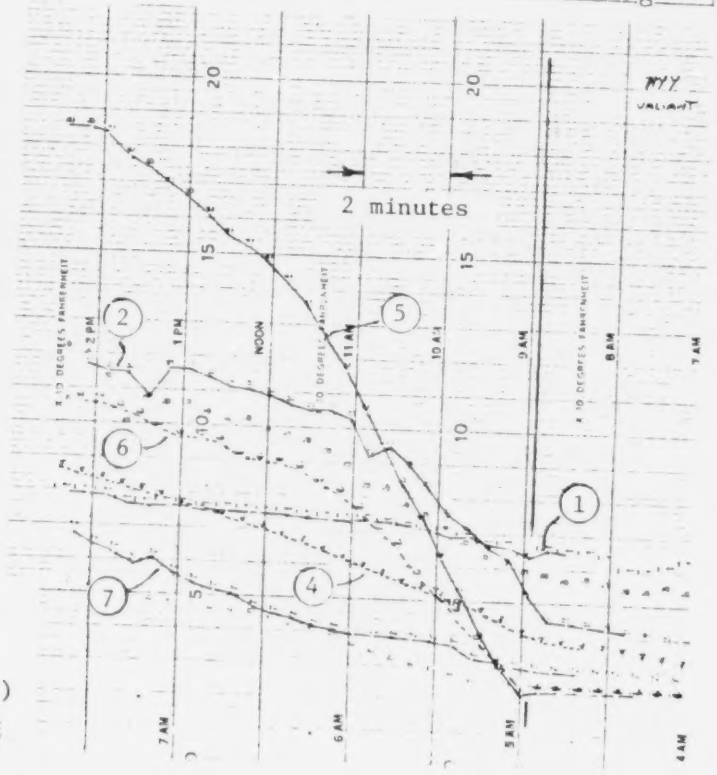

Figure 30
'70 Valiant
NYC Following Overnight
Soak at Outside Ambient (20°F)

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Table 2

CO Emissions in grams/mile

Vehicles Fully Warmed

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	30.9	25.4	8.3	0.5	4.1
Bag 1	34.0	19.4	12.1	1.0	4.1
Bag 2	28.1	30.9	4.8	0.1	4.1
NYC	107.[illegible]	76.3	20.2	3.2	7.2

Vehicles Soaked Overnight at Room Temp. (approx. 77°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	42.5	33.1	13.4	2.8	5.5
Bag 1	90.0	66.7	39.7	12.5	7.6
Bag 2	28.3	27.1	3.7	0.0	5.5
Bag 3	34.0	19.4	12.1	1.0	4.1
NYC	301.0	188.4	72.6	16.3	20.2

Vehicles Soaked Overnight at Outside Ambient (10-25°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	68.3	47.1	32.2	18.0	12.2
Bag 1	140.3	120.8	131.0	85.8	41.9
Bag 2	56.9	32.9	3.7	0.1	5.2
Bag 3	35.9	18.6	11.9	1.0	3.2
NYC	444.7	330.0	335.1	223.9	125.9

Table 3

CO Emissions in grams/minute

Vehicles Fully Warmed

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
Bag 1	14.40	8.27	5.16	0.43	1.75
NYC	12.66	9.02	2.38	0.38	0.85

Overnight Soak at Room Temp. (approx. 77°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
Bag 1	38.18	28.45	16.93	5.33	3.24
NYC	35.58	22.27	8.60	1.93	2.39

Overnight Soak at Outside Ambient (10-25°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
Bag 1	59.84	51.52	55.87	36.59	17.87
NYC	52.56	39.01	41.97	26.46	14.88

Table 4

'70 Valiant

'75 FTP Soaked at Room Temp. (approx. 77°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	42.5	90.0	28.3	34.0	43.6	34.6	21.8
4 hours	49.0	71.4	48.1	34.0	30.0	51.1	18.9
2 hours	42.2	47.6	44.3	34.0	23.2	54.8	22.0
1 hour	57.5	68.9	65.4	34.0	24.6	59.2	16.1
fully warmed	30.9	34.0	28.1	34.0	22.6	47.4	30.0

'75 FTP Soaked at Outside Ambient (10-25°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	68.3	140.3	56.9	35.9	42.3	43.4	14.3
4 hours	46.1	81.7	37.4	35.9	36.5	42.3	21.3
2 hours	43.7	67.6	38.3	35.9	31.9	45.7	22.4
1 hour	-	-	-	-	-	-	-

Table 5

'70 Impala

'75 FTP Soaked at Room Temp. (approx. 77°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	33.1	66.7	27.1	19.4	41.4	42.6	16.0
4 hours	25.3	27.4	27.5	19.4	22.3	56.7	21.0
2 hours	24.0	20.8	27.6	19.4	17.9	60.0	22.1
1 hour	23.3	19.0	27.0	19.4	16.8	60.4	22.8
fully warmed	25.4	19.4	30.9	19.4	15.7	63.4	20.9

'75 FTP Soaked at Outside Ambient (10-25°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	47.1	120.8	32.9	18.6	52.8	36.4	10.8
4 hours	45.4	101.1	37.4	18.6	45.9	42.9	11.2
2 hours	31.9	47.6	32.7	18.6	23.1	59.2	17.7

Table 6

'76 Impala

'75 FTP Soaked at Room Temp. (approx. 77°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	13.4	39.7	3.7	12.1	61.1	14.3	24.6
4 hours	8.0	14.4	3.4	12.1	36.9	22.2	40.9
2 hours	8.6	14.0	4.7	12.1	33.6	28.2	38.2
1 hour	7.3	11.0	3.3	12.1	31.0	23.8	45.1
fully warmed	8.3	12.1	4.8	12.1	30.1	30.1	39.9

'75 FTP Soaked at Outside Ambient (10-25°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	32.2	131.0	3.7	11.9	83.8	6.1	10.1
4 hours	25.5	99.0	3.6	11.9	79.9	7.3	12.7
2 hours	9.2	20.2	3.5	11.9	45.0	19.8	35.2
1 hour	8.1	14.5	3.5	11.9	37.0	22.8	40.2

Table 7

'76 Granada

'75 FTP Soaked at Room Temp. (approx. 77°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	2.8	12.5	0.0	1.0	90.0	0.7	9.3
4 hours	2.3	9.9	0.1	1.0	86.8	1.9	11.3
2 hours	1.5	5.8	0.1	1.0	80.3	2.0	17.8
1 hour	1.0	2.9	0.2	1.0	62.8	9.4	27.8
fully warmed	0.5	1.0	0.1	1.0	39.5	8.1	52.4

'75 FTP Soaked at Outside Ambient (10-25°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	18.0	85.8	0.1	1.0	98.3	0.2	1.5
4 hours	13.0	61.5	0.2	1.0	97.2	0.9	2.0
2 hours	2.8	11.5	0.3	1.0	85.5	5.0	9.5
1 hour	0.8	2.4	0.1	1.0	61.9	4.3	33.8

Table 8

'76 CVCC Civic

'75 FTP Soaked at Room Temp. (approx. 77°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	5.5	7.6	5.5	4.1	28.0	51.6	20.4
4 hours	5.2	6.2	5.5	4.1	24.2	54.2	21.5
2 hours	4.5	4.9	4.5	4.1	22.5	52.5	25.0
1 hour	4.5	4.6	4.7	4.1	20.9	54.2	24.9
fully warmed	4.1	4.1	4.1	4.1	20.7	51.9	27.4

'75 FTP Soaked at Outside Ambient (10-25°F)

Soak Time	CO Emissions grams/mile				Percent of '75 FTP		
	'75 FTP	Bag 1	Bag 2	Bag 3	Bag 1	Bag 2	Bag 3
Overnight	12.2	41.9	5.2	3.2	70.7	22.1	7.1
4 hours	7.2	17.9	5.1	3.2	51.2	36.7	12.1
2 hours	5.2	6.7	5.7	3.2	26.4	56.9	16.7
1 hour	4.8	7.2	4.7	3.2	30.9	50.9	18.1

Table 9

'75 FTP Overnight Soak at Room Temp. (approx. 77°F)

Bag 1 CO Emissions in Grams/Mile

Mode	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
1	301.6	237.8	104.2	46.5	14.5
2	42.6	28.3	29.8	4.64	5.48
3	42.4	24.4	11.7	5.63	7.05
4	27.5	20.8	15.6	2.61	6.29

Modal CO Emissions as Percent of Bag 1 Emissions

Mode	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
1	63.5	67.57	49.70	70.54	36.44
2	26.0	23.28	41.08	20.38	39.76
3	6.7	5.24	4.22	6.44	13.34
4	3.8	3.92	4.93	2.63	10.46

Table 10

'75 FTP Overnight Soak at Outside Ambient (10-25°F)

Bag 1 CO Emissions in Grams/Mile

Mode	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
1	367.9	400.0	351.4	292.1	125.1
2	101.1	68.2	110.4	53.8	29.4
3	61.4	28.7	18 8	3.09	9.45
4	50.9	27.8	9.63	4.20	5.53

Modal CO Emissions as Percent of Bag 1 Emissions

Mode	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
1	49.7	62.72	50.80	64.39	56.60
2	39.5	30.98	46.22	34.33	38.51
3	6.3	3.40	2.06	0.52	3.23
4	4.6	2.90	0.92	0.76	1.66

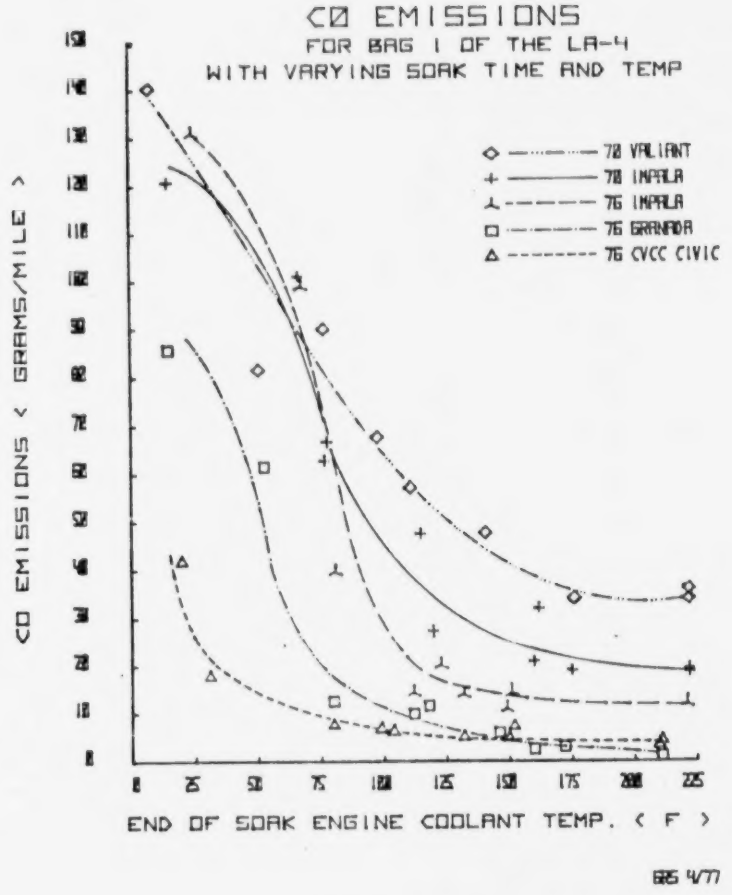


Figure 31

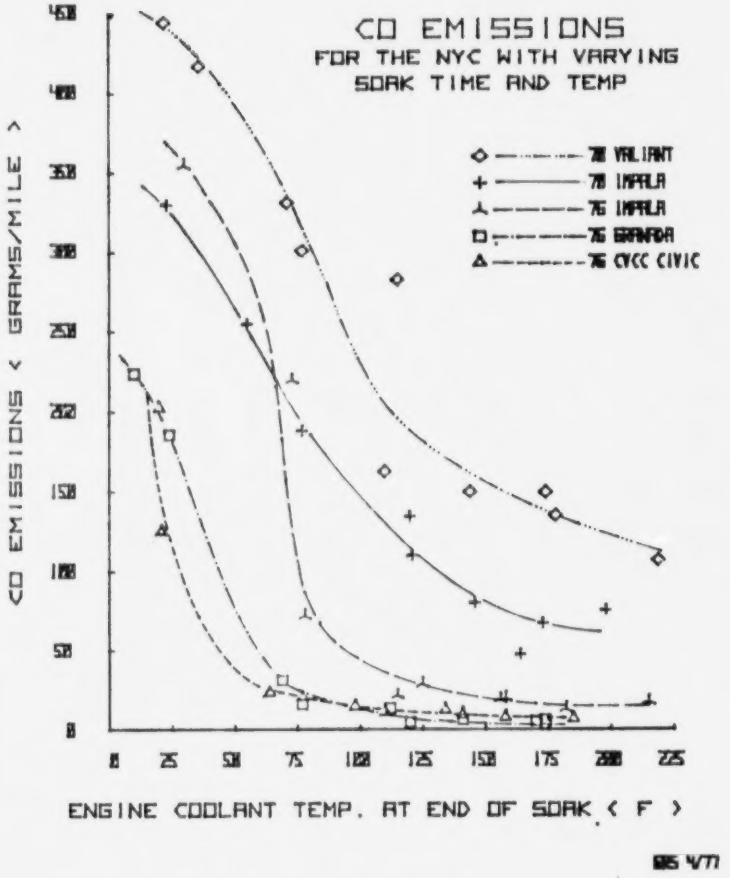
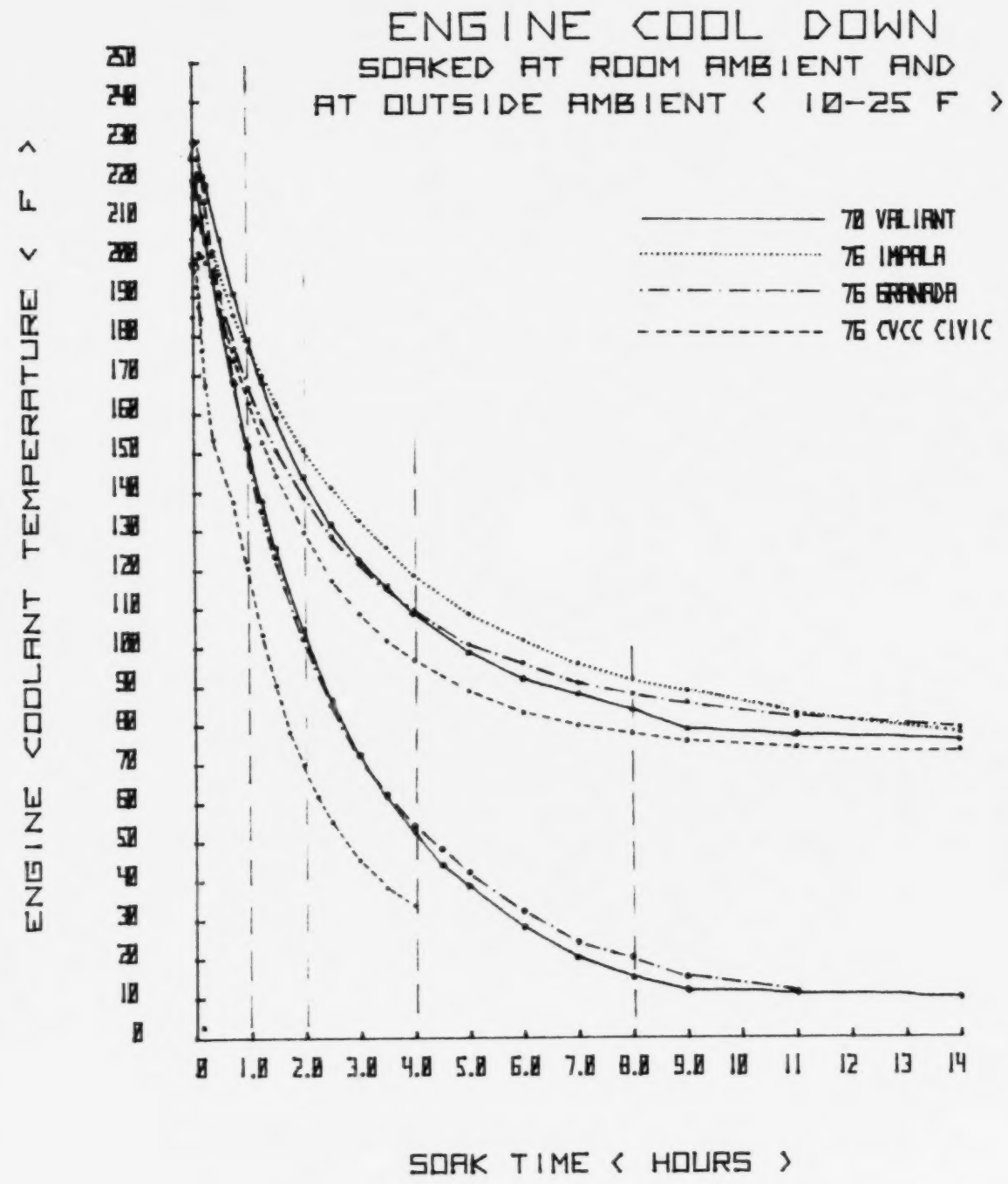


Figure 32

Figure 33



GRS 4/77

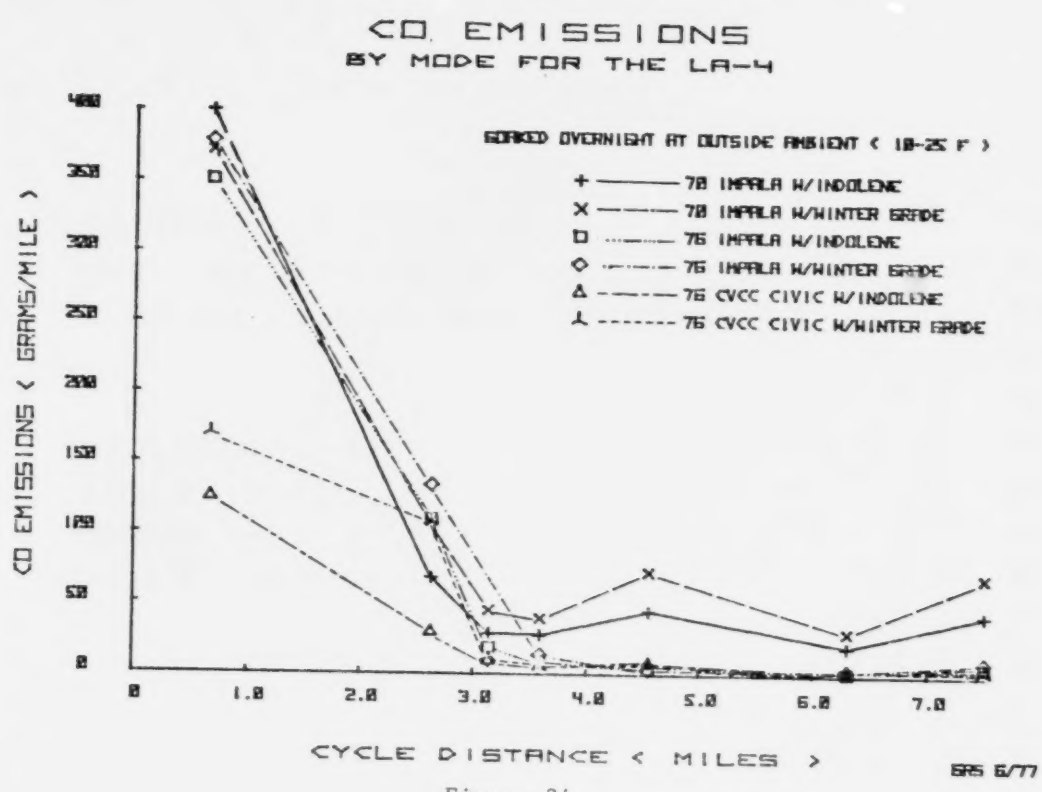


Figure 34

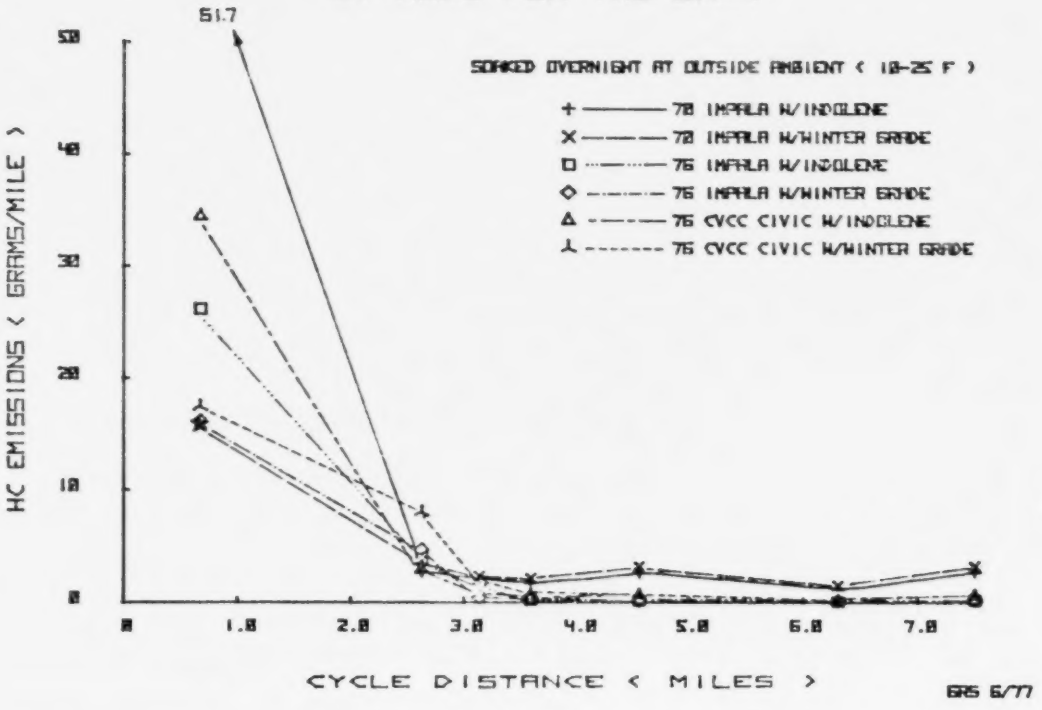
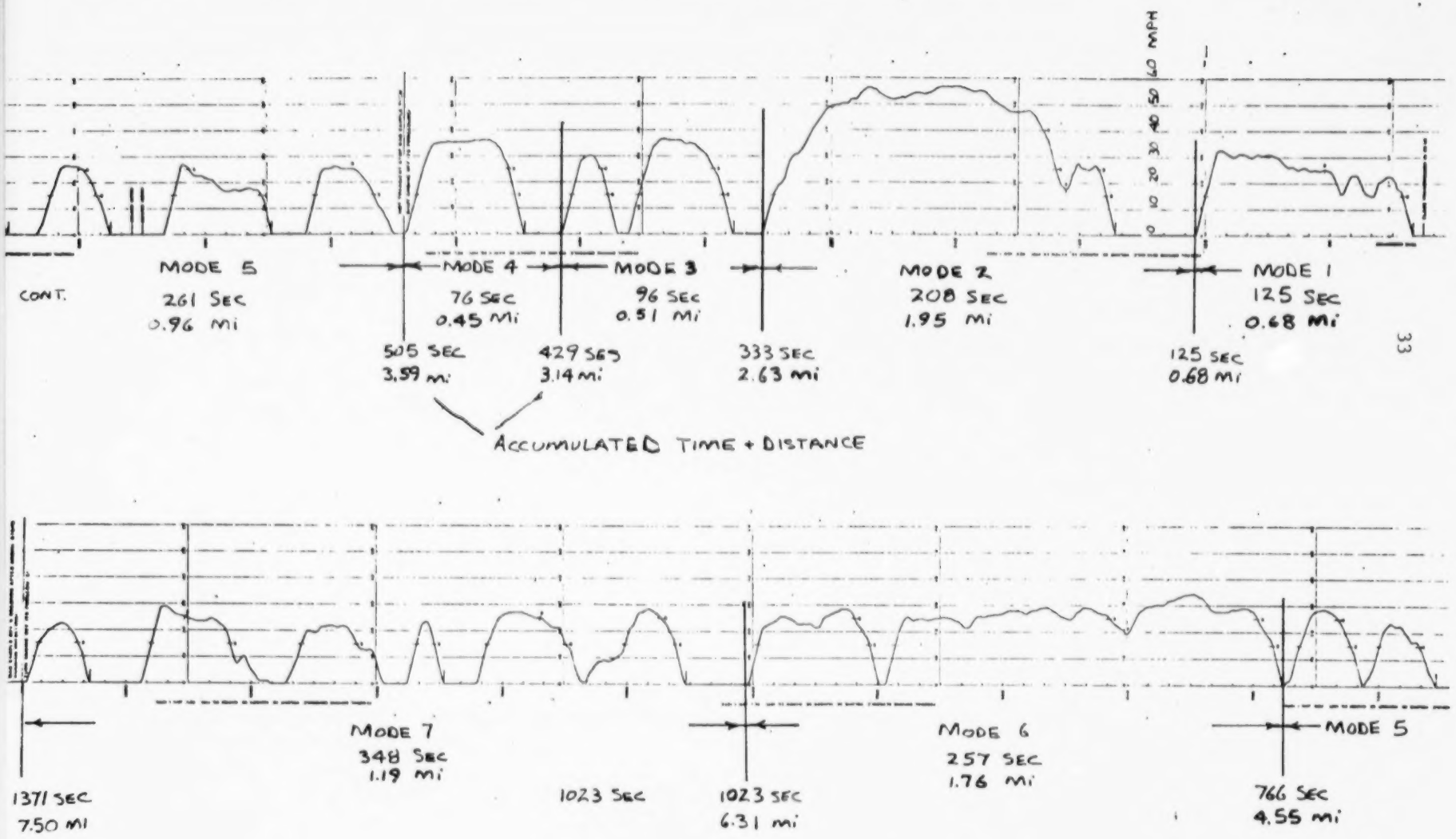


Figure 35

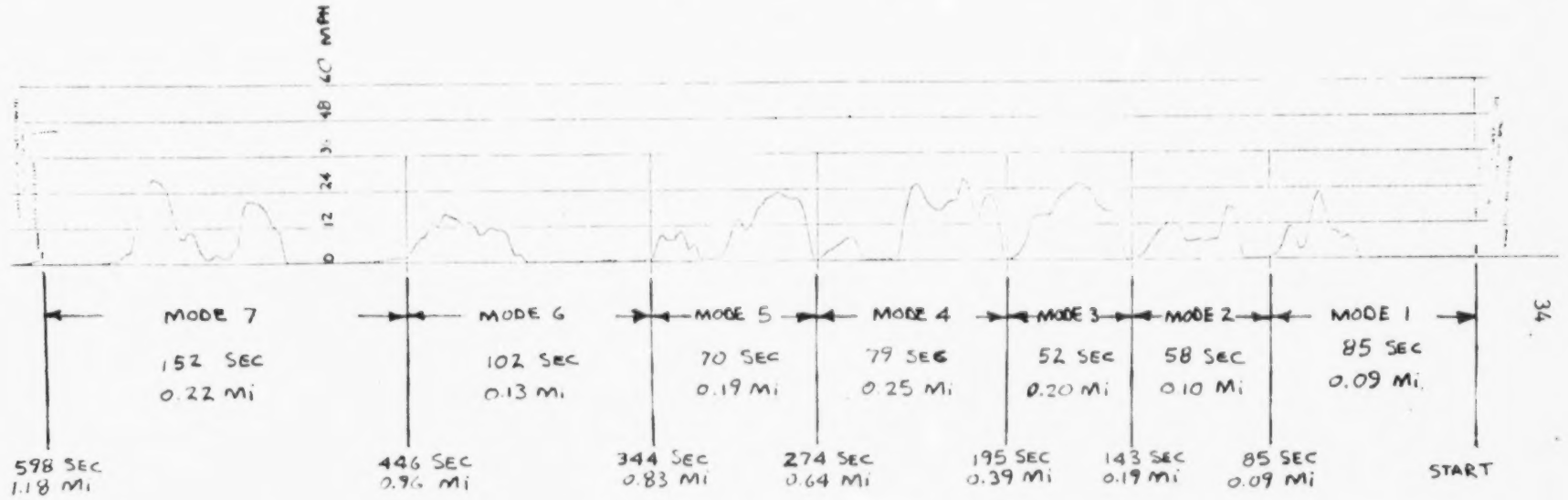
Appendix A-1

LA-4 Driving Cycle Showing Delineation of the Seven Modes



Appendix A-2

NYC DRIVING CYCLE SHOWING DELINEATION OF THE SEVEN MODES



Appendix B-1

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1970 Plymouth Valiant
Emission control system - Engine modification

Engine

type	4 stroke Otto Cycle, OHV, in-line 6 cyl.
bore x stroke	3.40 x 4.12 in./86.4 x 104.8 mm
displacement	225 CID/3688 cc
compression ratio	8.4:1
maximum power @ rpm	145 hp/108 kW @ 4000 rpm
fuel metering	single 1 barrel carburetor
fuel requirement	94 RON

Drive Train

transmission type	3 speed automatic
final drive ratio	2.76:1

Chassis

type	unitized construction, front engine, rear wheel drive
tire size	C 78-14
curb weight	2920 lb/1325 kg
inertia weight	3500 lb
passenger capacity	5

Emission Control System

basic type	engine modification, positive crankcase ventilation (PCV)
mileage on vehicle	24,500

Appendix B-2

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1970 Chevrolet Impala
Emission control system - Engine modification

Engine

type	4 stroke Otto Cycle, OHV, V-8
bore x stroke	4.00 x 3.48 in/102 x 88 mm
displacement	350 CID/5700 cc
compression ratio	9.00/1
maximum power @ rpm	250 HP/186 kW @ 4800 RPM
fuel metering	single 2 barrel carburetor
fuel requirement	94 RON

Drive Train

transmission type	automatic
final drive ratio	2.73:1

Chassis

type	body/frame, front engine, rear wheel drive
tire size	H 78 x 15
curb weight	3888 lbs/1764 kg
inertia weight	4500 lb
passenger capacity	6

Emission Control System

basic type	engine modification, PCV
mileage on vehicle	23,800 mi

Appendix B-3

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1976 Chevrolet Impala
Emission control system - Catalyst, EGR

Engine

type . . . . . 4 stroke, Otto cycle, OHV, V-8
bore x stroke . . . . . 4.00 x 3.48 in/101.6 x 88.4 mm
displacement . . . . . 350 cu in/ 5735 cc
compression ratio 8.5:1
maximum power @ rpm . . . . . .
fuel metering . . . . . single 2 barrel carburetor
fuel requirement . . . . . 91 RON unleaded

Drive Train

transmission type . . . . . automatic
final drive ratio 2.73:1

Chassis

type . . . . . body/frame, front engine, rear wheel drive
tire size . . . . . HR 78 x 15
curb weight . . . . . 4266 lb/1935 kg
inertia weight . . . . . 5000 lb
passenger capacity 6

Emission Control System

basic type . . . . . Single Pelletted noble metal catalyst
Exhaust Gas Recirculation (EGR)
Early Fuel Evaporative System (EFE)
Positive Crankcase Ventilation (PCV)

mileage on vehicle . . . . . 4,600 mi

Appendix B-4

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1976 Ford Granada
Emission control system - Catalyst, EGR, air injection

Engine

type . . . . . 4 stroke Otto cycle, OHV, in-line 6 cyl.
bore x stroke . . . . . 3.68 x 3.91 in/93 x 99 mm
displacement 250 CID/4100cc
compression ratio 8.0:1
maximum power @ rpm . . . . . 86 hp/64 kW @ 3000 rpm
fuel metering . . . . . single 1 barrel carburetor
fuel requirement . . . . . 91 RON unleaded

Drive Train

transmission type . . . . . automatic
final drive ratio 3.07:1

Chassis

type . . . . . unitized body, front engine, rear wheel drive
tire size . . . . . DR 78-14
curb weight . . . . . .
inertia weight . . . . . 4000 lb
passenger capacity 5

Emission Control System

basic type . . . . . single monolith noble metal catalyst,
secondary air injection (AIR), EGR, PCV

mileage on vehicle 5,800

Appendix B-5

TEST VEHICLE DESCRIPTION

Chassis model year/make - 1976 Honda CVCC Civic
Emission control system - Honda CVCC

Engine

type	4 stroke pre-chamber, stratified charge, spark ignited, single OHC, in-line 4 cyl
bore x stroke	2.91 x 3.41 in/74 x 86.5 mm
displacement	90.8 CID/1488 cc
compression ratio	7.9:1
maximum power @ rpm	60 hp/27 kW @ 5000 rpm
fuel metering	single carburetor with progressive 2 bbl for combustion chamber and 1 bbl for pre-chamber
fuel requirement	91 RON

Drive Train

transmission ratio	4 speed manual
final drive ratio	3.875:1

Chassis

type	unitized body, front transverse mounted engine, front wheel drive
tire size	6.00 S12
curb weight	1795 lb/814 kg
inertia weight	2000 lb.
passenger capacity	4

Emission Control System

basic type	Honda Compound Vortex Controlled Combustion (CVCC) which is basically a pre-chamber stratified charge engine with a thermal reactor and PCV
mileage on vehicle	5,000 mi.

APPENDIX C

Cold Start from Room Temp. (77°F) All Vehicles.

HC Emissions Figures C-1 and C-2

The HC emissions displayed the same trends as the CO emissions, i.e. much higher mode 1 emissions that rapidly declined to fully warmed emission levels. The NYC cycle grams/mile CO emissions were roughly five times those of the '75 FTP. The higher CO emitters, the two "pre-control" cars, were also the higher HC emitters.

The major difference between the HC and CO trends was the spread of the five cars mode 1 emissions. For the CO emissions the '76 CVCC had the lowest emissions, then came the '76 Granada at roughly four times the CVCC CO level, then the '76 Impala at 8-10 times the CVCC CO level and then the '70 Impala at roughly 20 times the '76 CVCC CO level. The '70 Valiant CO emissions were the highest but because of the apparently erratic choke operation their validity is suspect. By contrast mode 1 HC emissions of all the cars (excluding the '70 Valiant) are within a factor of 1.5.

NOx Emissions Figures C-3 and C-4

The NOx emissions were not strongly affected by the cold start from room temperature. Of equal or greater influence on NOx emissions was the mode by mode differences in the driving cycles. On any given vehicle, these differences produced NOx values differing by factors of 2 to 4. Two exceptions were the '76 Granada and '76 Impala during mode 1 of the NYC, where their NOx emissions were 3 to 4 times that of the other cars.

Unlike the HC and CO emissions, the NOx emission levels were approximately the same for both the '75 FTP and NYC cycles.

Fuel Economy Figures C-5 and C-6

As expected, the mode 1 fuel economy was lower but again mode by mode differences in the driving cycles produce fuel economy ranges greater than the cold versus warm engine. The much lower modes 1 and 2 fuel economy for the NYC cycle are due more to the driving cycle than to the cold start condition as can be seen in Appendix D.

Appendix C

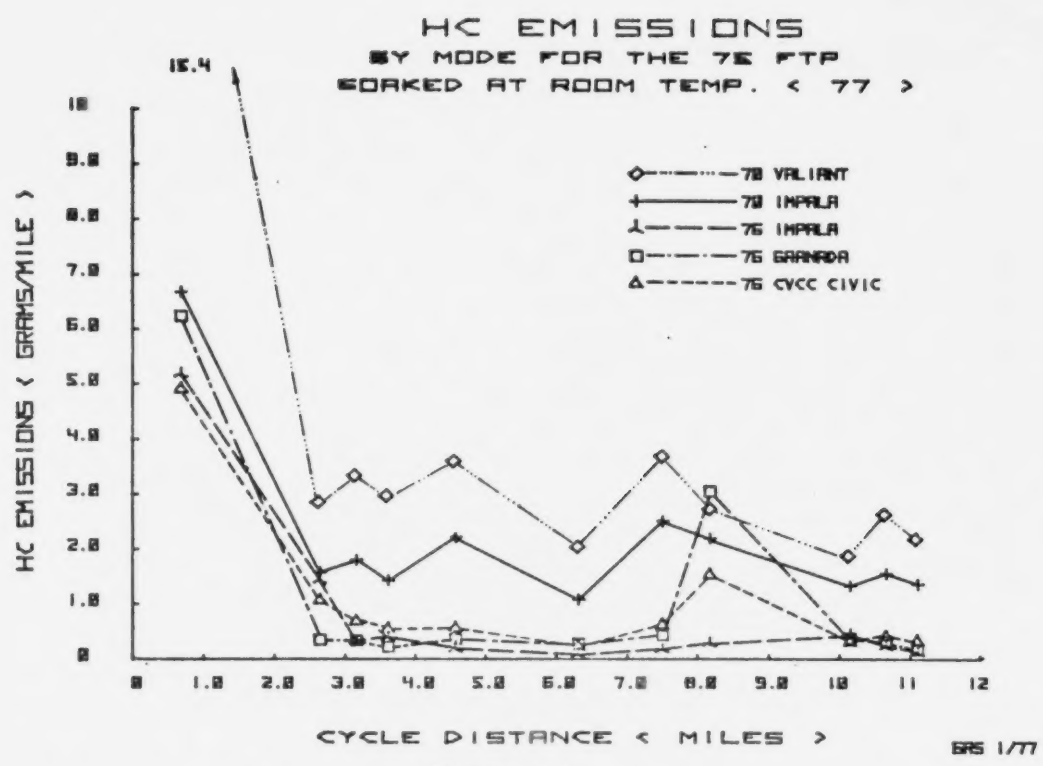


Figure C-1

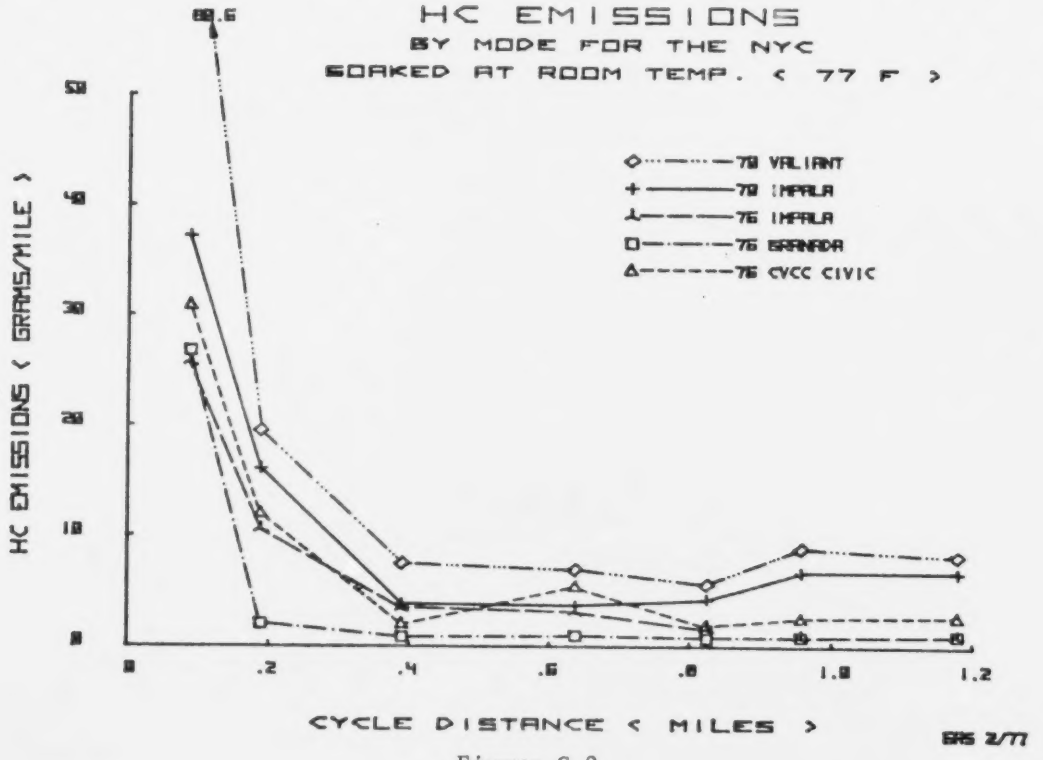


Figure C-2

Appendix C

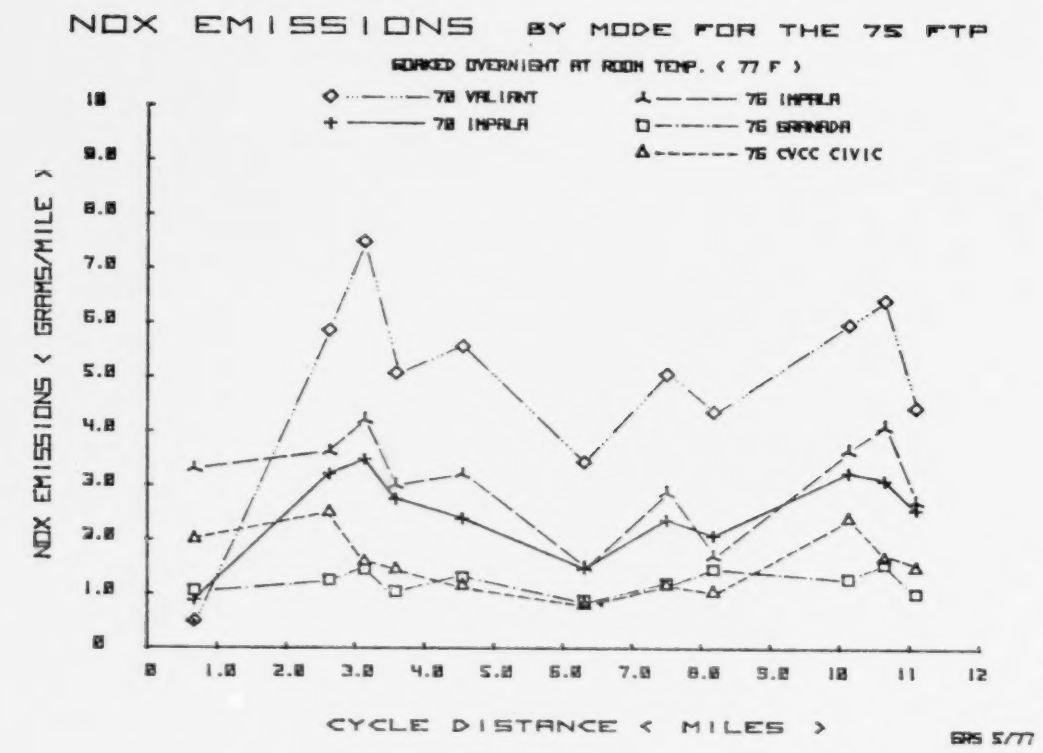

NOX EMISSIONS BY MODE FOR THE 75 FTP
SOAKED OVERNIGHT AT ROOM TEMP. (77 F)
78 VALIANT
78 IMPALA
76 IMPALA
76 GRANADA
76 CVCC CIVIC
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
BRS 5/77

Figure C-3

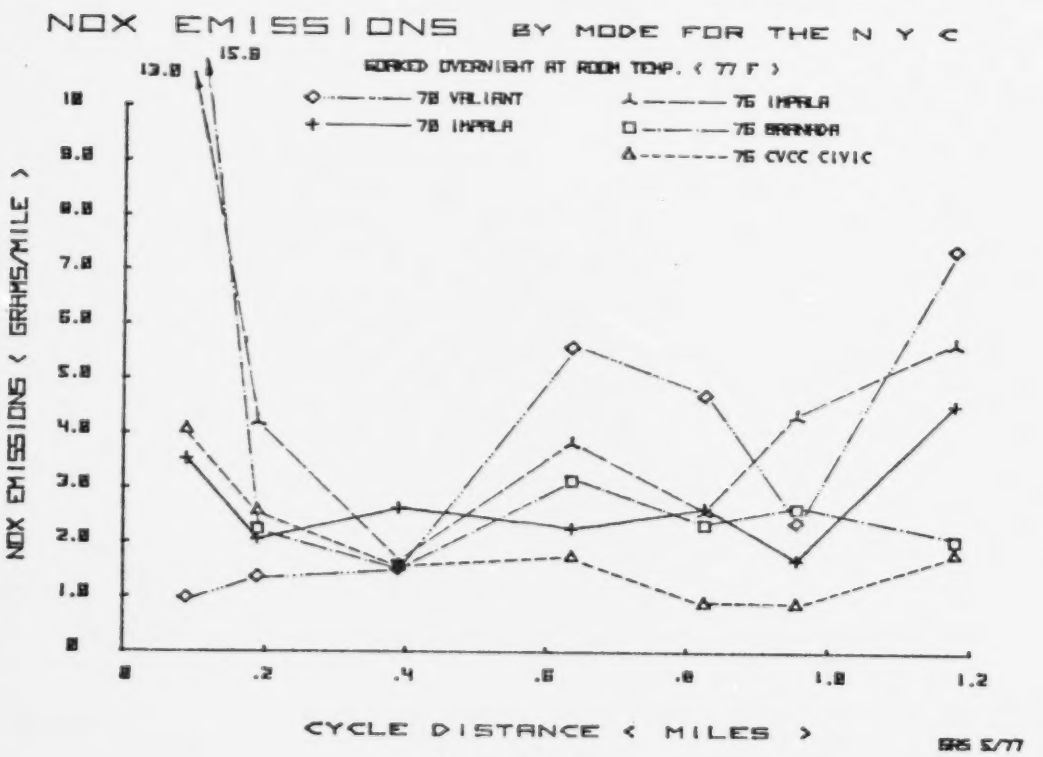

NOX EMISSIONS BY MODE FOR THE N Y C
SOAKED OVERNIGHT AT ROOM TEMP. (77 F)
78 VALIANT
78 IMPALA
76 IMPALA
76 GRANADA
76 CVCC CIVIC
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
BRS 5/77

Figure C-4

Appendix C

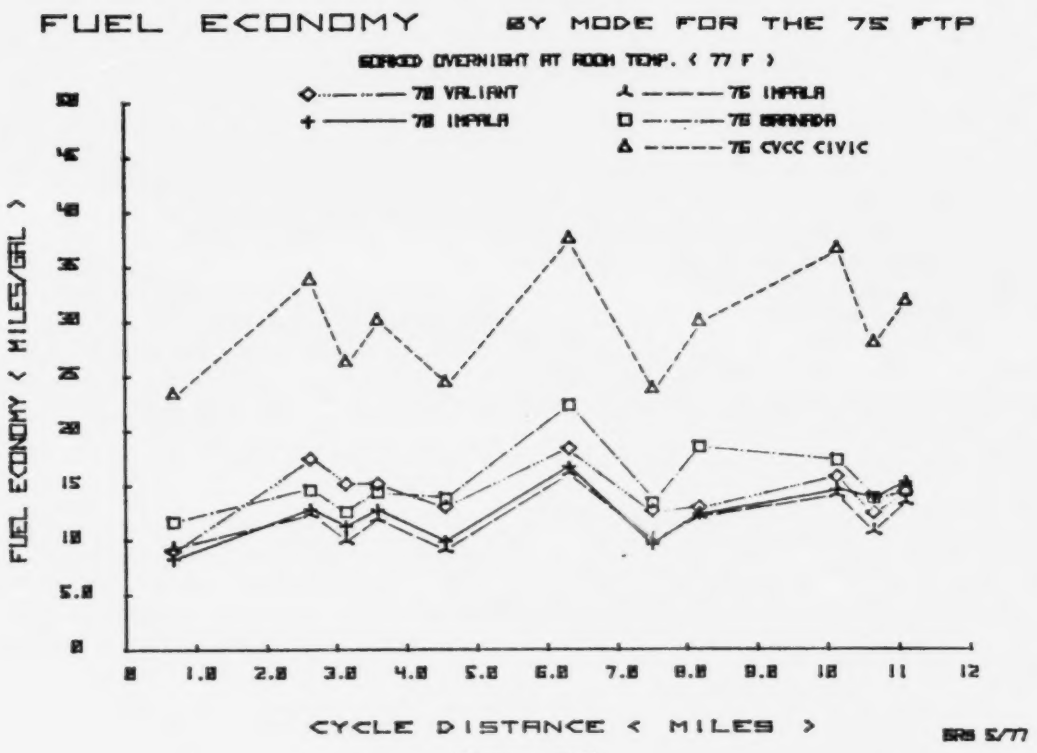

FUEL ECONOMY BY MODE FOR THE 75 FTP
SOAKED OVERNIGHT AT ROOM TEMP. (77 F)
78 VALIANT
78 IMPALA
75 IMPALA
75 GRANADA
75 CVCC CIVIC
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
BRS 5/77

Figure C-5

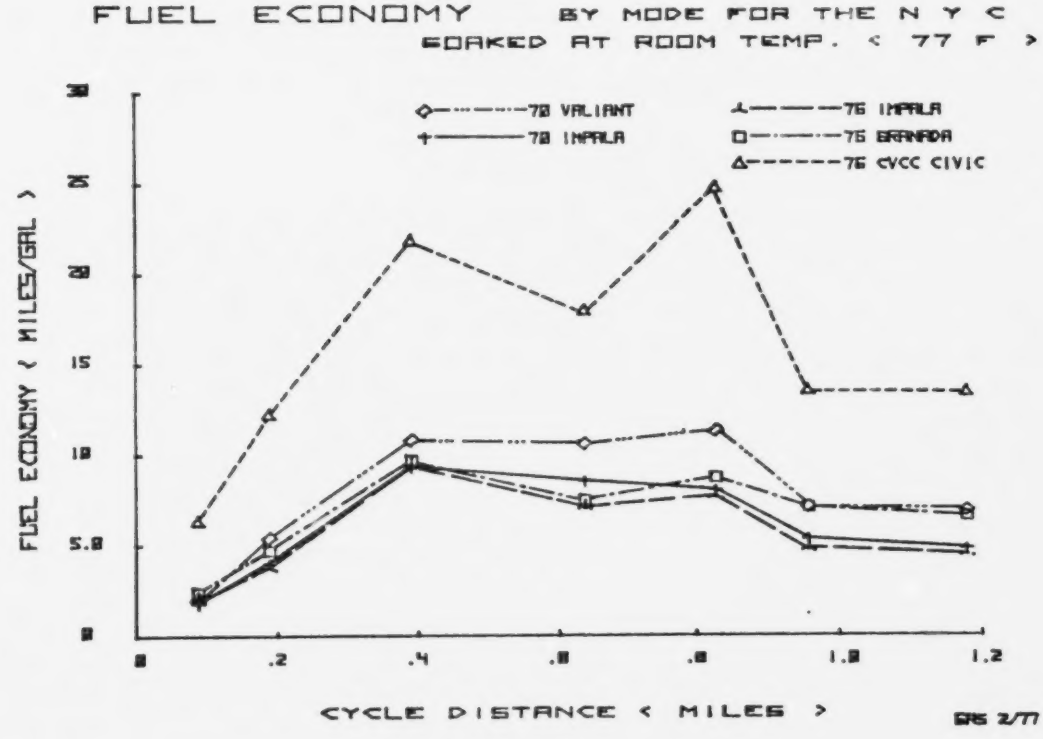

FUEL ECONOMY BY MODE FOR THE N Y C
SOAKED AT ROOM TEMP. (77 F)
78 VALIANT
78 IMPALA
75 IMPALA
75 GRANADA
75 CVCC CIVIC
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
BRS 2/77

Figure C-6

APPENDIX D

Varying Soak Times at Room Temp. (77° F)

HC Emissions Figures D-1 through D-10

The effect of varying soak times on HC emissions was very similar to the effect on CO emissions. The HC emissions had largely decayed to the fully warmed levels after 0.67 miles and 125 seconds for the LA-4 and 0.19 miles and 143 seconds for the NYC cycle. In contrast, however, there was no relatively larger increase in mode 1 HC emissions associated with an incremental increase in soak time. For CO a large increase in emission levels occurred between the 4 hour and overnight soak times. With the exception of the '70 Valiant, each step increase in soak time brought a roughly uniform increase in HC emissions.

NOx Emissions Figures D-11 through D-20

The effect of soak time at room temperature on NOx emissions appears to be largely technology dependent. For example, for the two pre-control cars, the mode 1 emissions increased from the overnight soak cold start to the fully warmed value. The opposite direction was displayed by the '76 model year cars. The '76 model cars had higher mode 1 NOx emissions following the overnight soak than for the fully warmed condition.

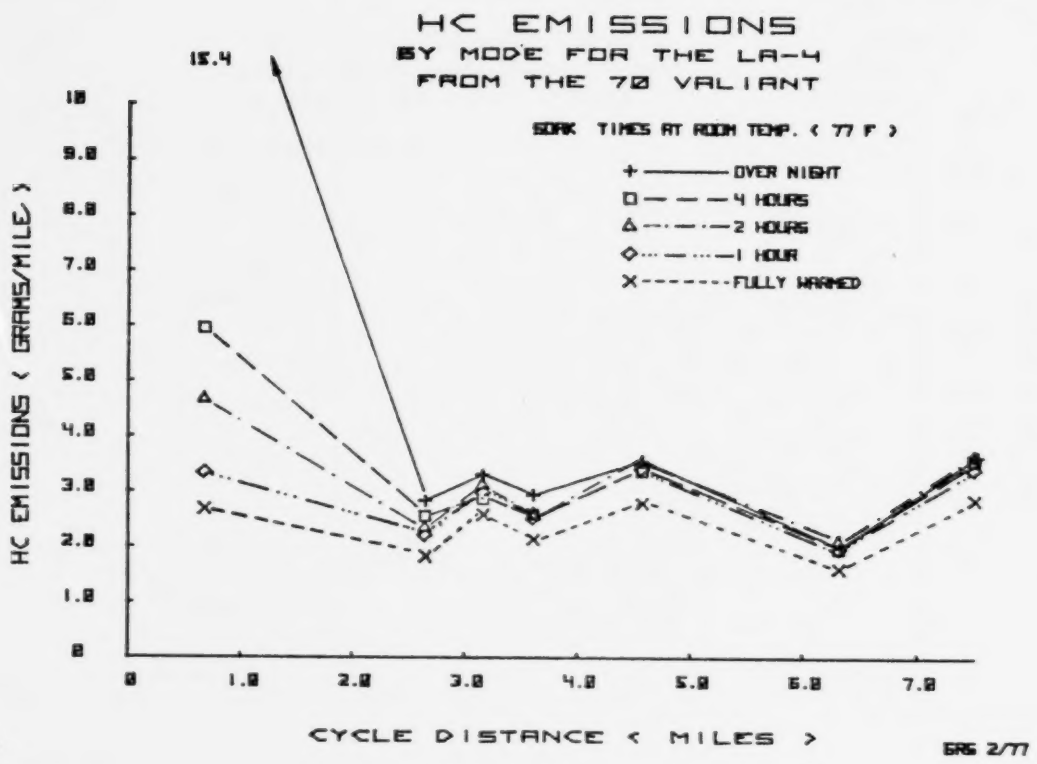
In nearly all cases the range of lowest to highest mode 1 NOx emissions was within a factor of 3.

The '76 Impala and '76 Granada had NYC cycle, overnight soak mode 1 NOx emissions that were considerably higher than those of the LA-4 mode 1. Since 60% of the mode 1 time for the NYC cycle is spent at idle this suggests that these two cars have choked idle conditions not conducive to NOx emission control. This problem is not evident in the LA-4 because so little mode 1 time is spent at idle.

Fuel Economy Figures D-21 through D-30

The effect on fuel economy of overnight soaks at room temperature was shown in Appendix C to be secondary to the effects produced by mode to mode cycle differences. The effects on mode 1 of varying soak times at room temperature were directionally as expected, i.e. in general fuel economy improved as soak time decreased. The order of magnitude of these changes was approximately equal to the test-to-test variability displayed in the other modes.

Appendix D



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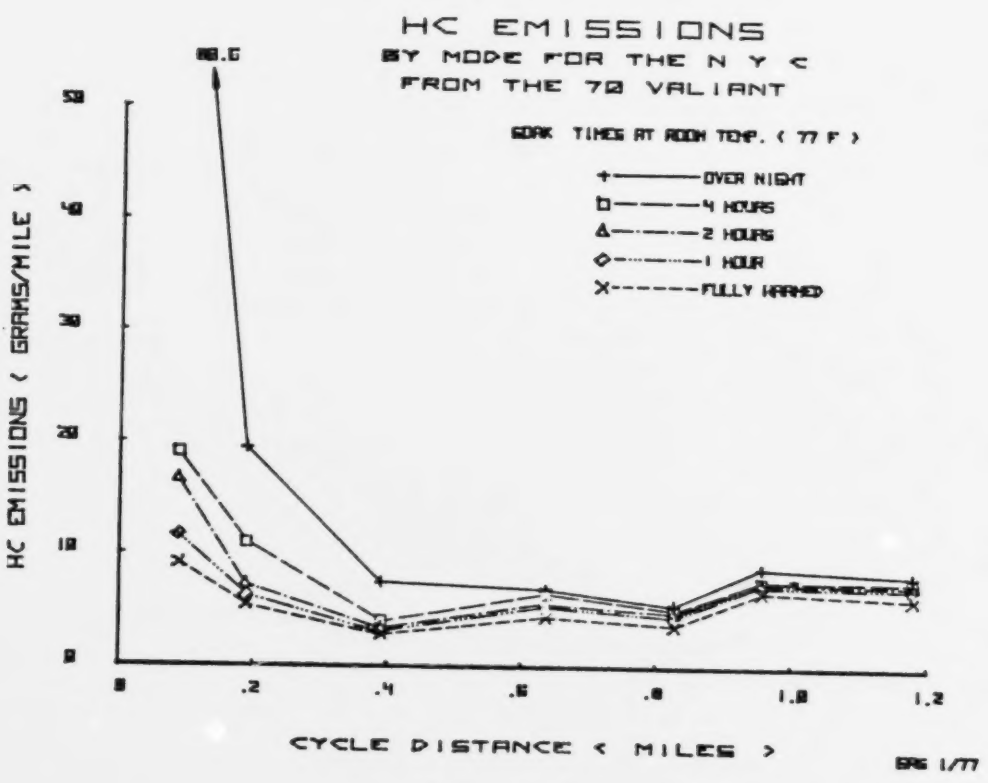
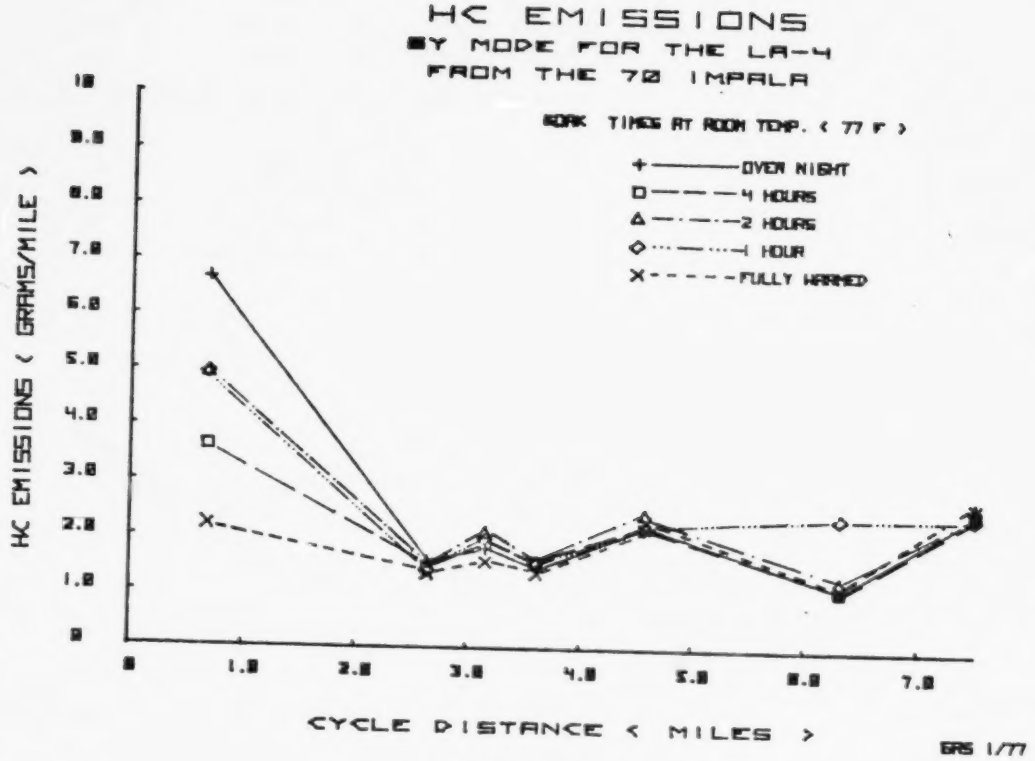


Figure D-2

Appendix D



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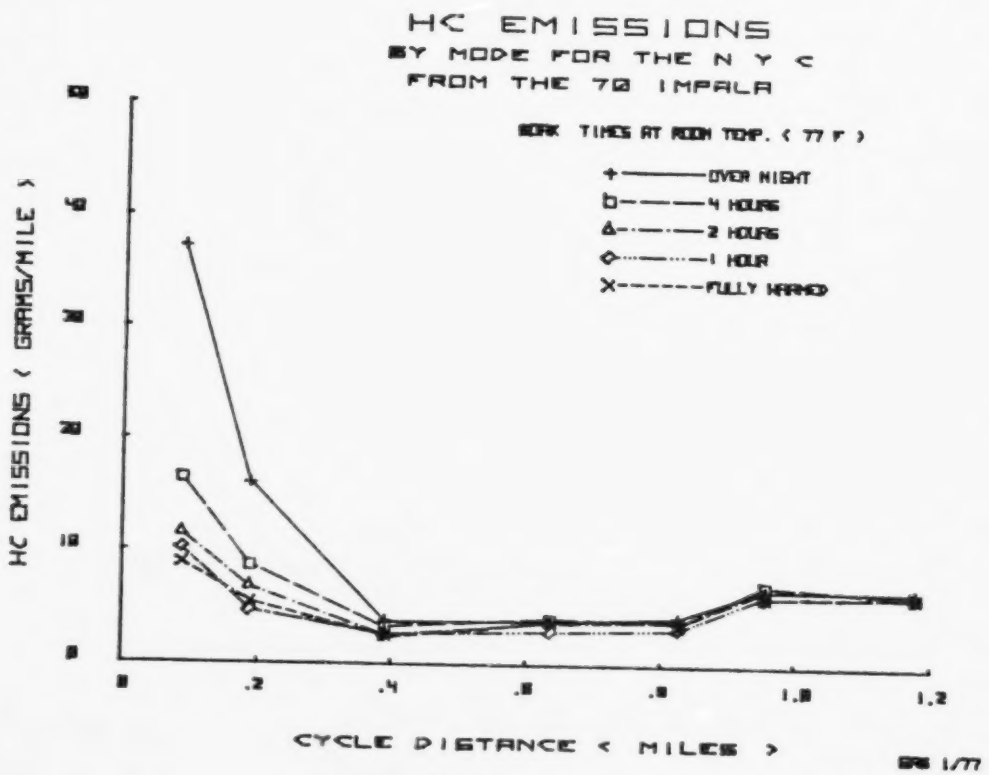

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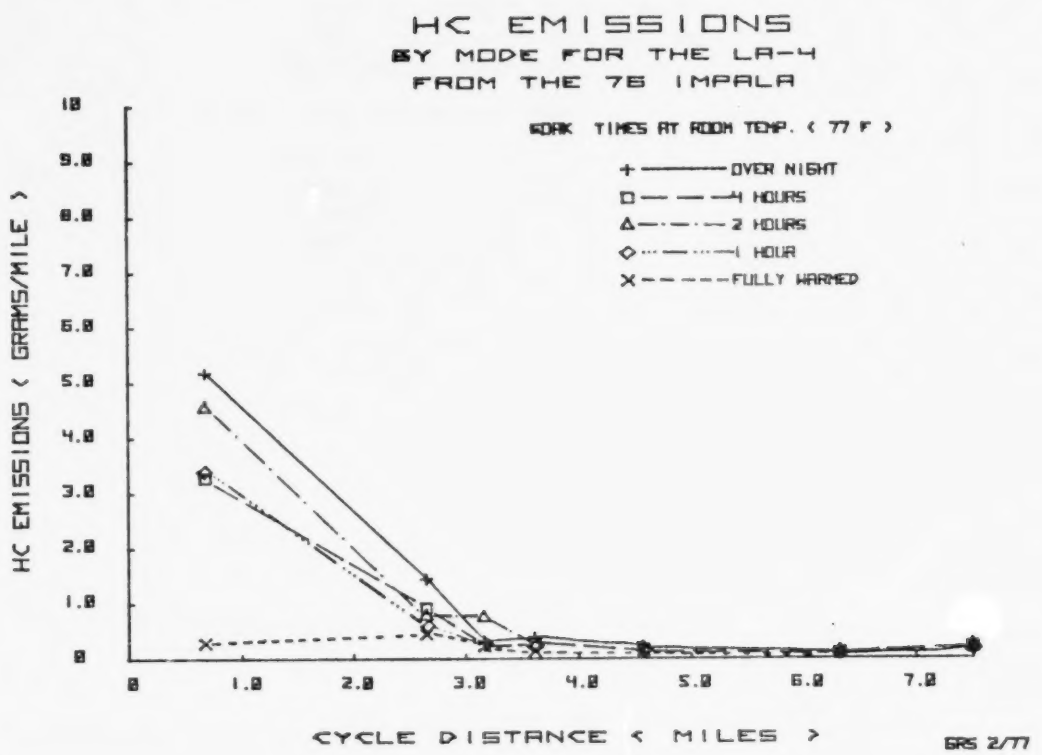
Appendix D



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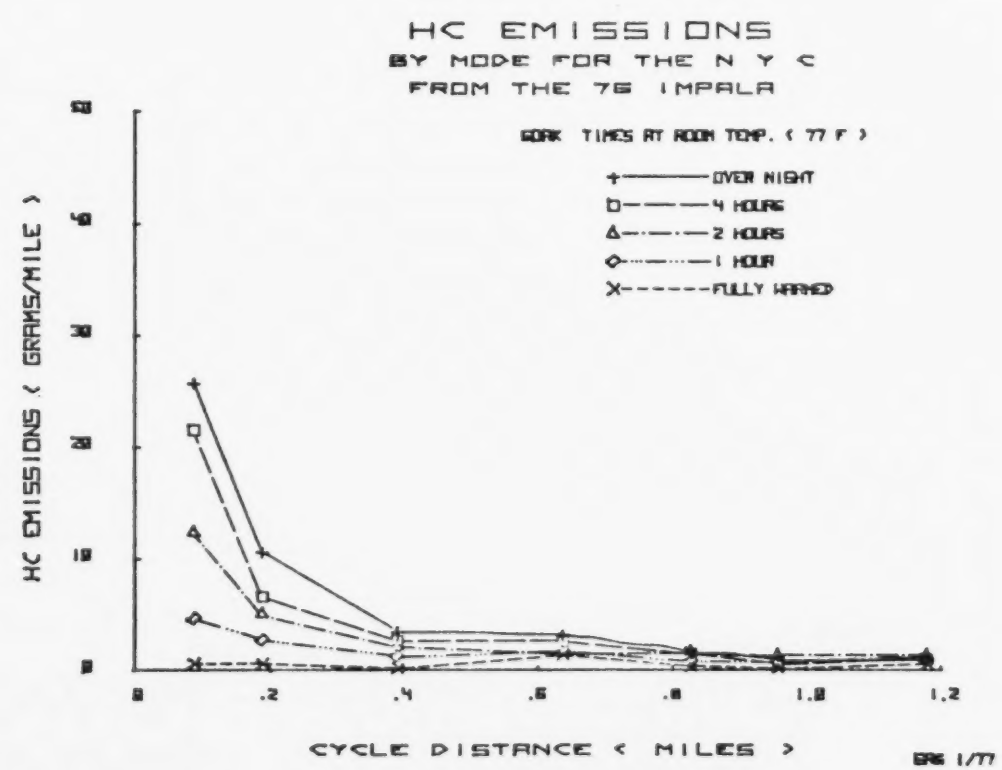

Figure D-6

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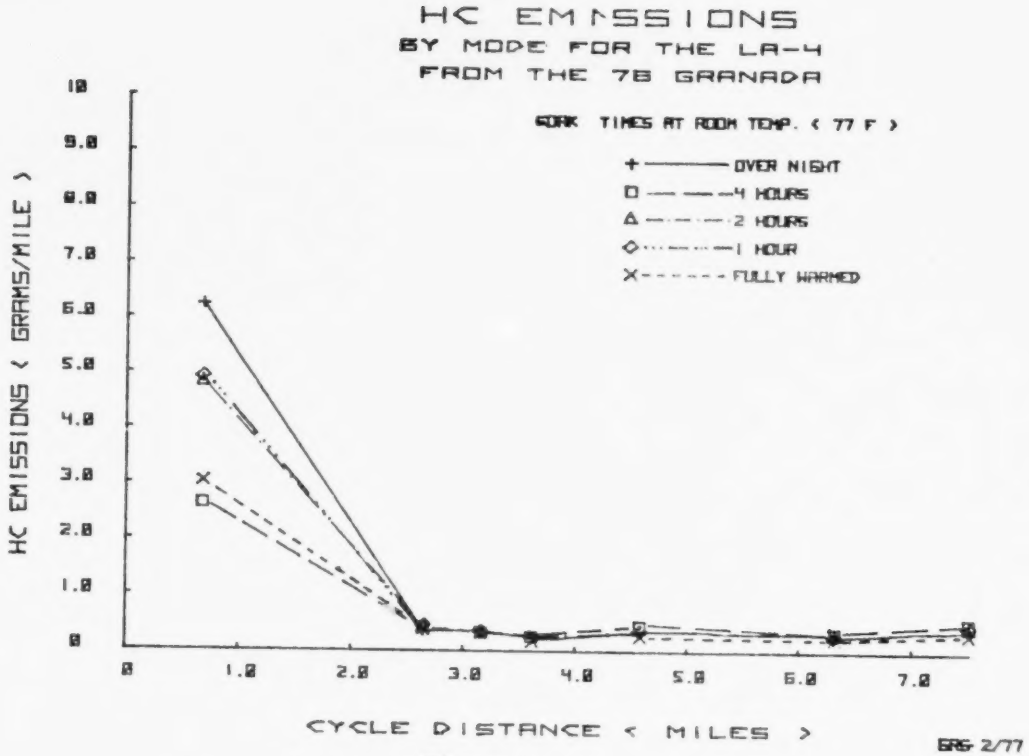

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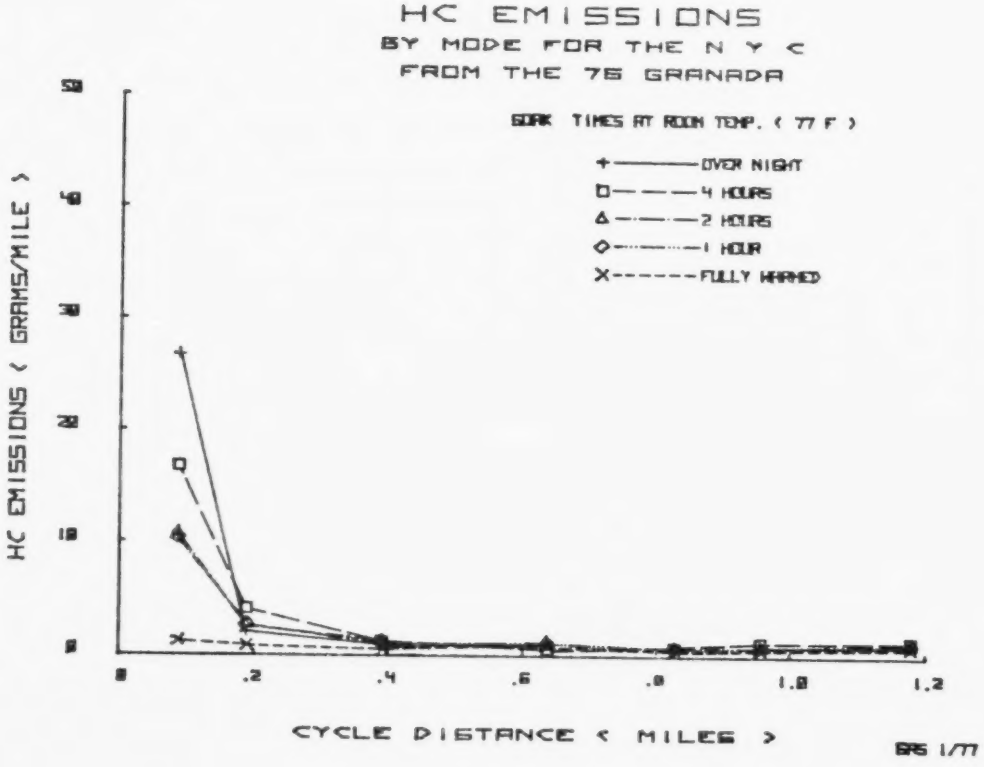

Figure D-8

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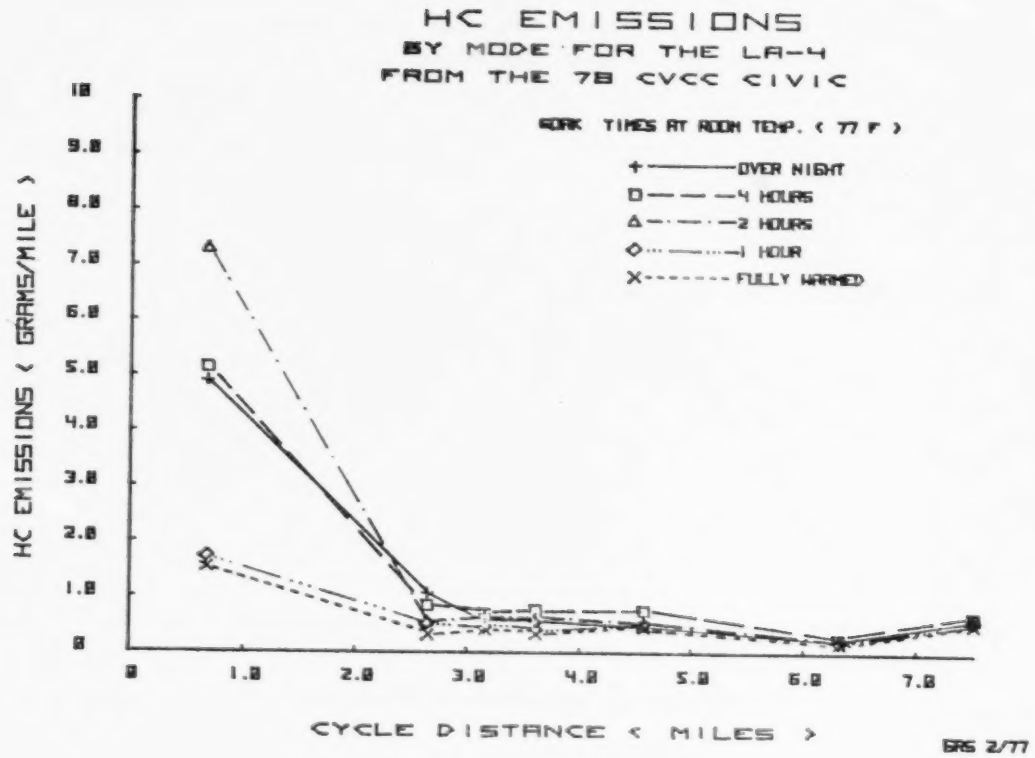

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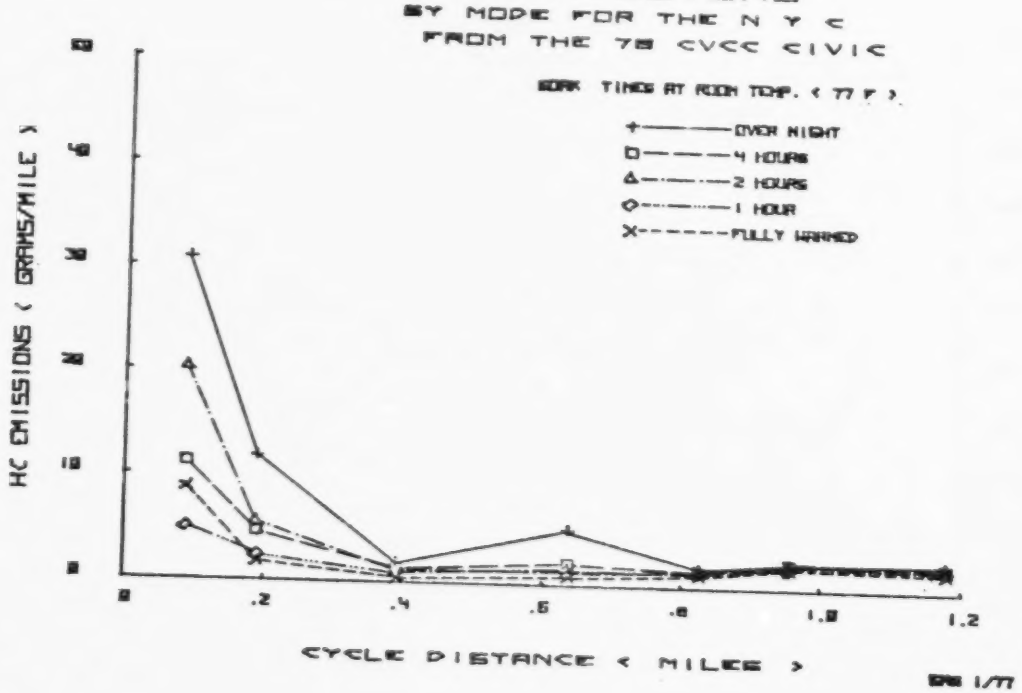

Figure D-10

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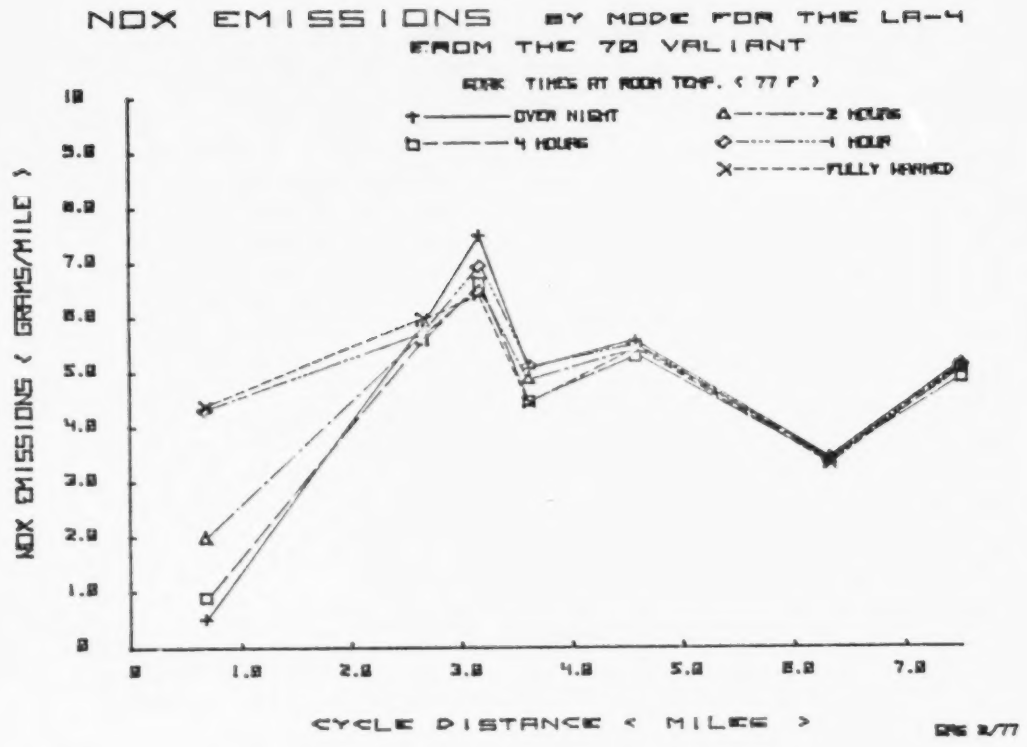

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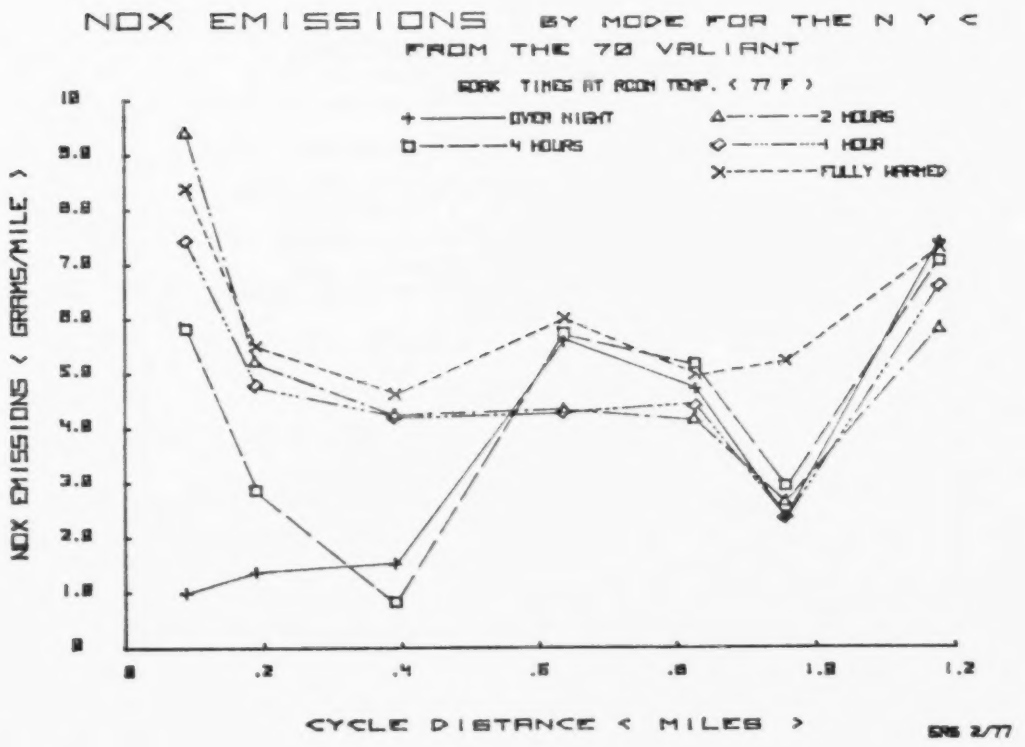
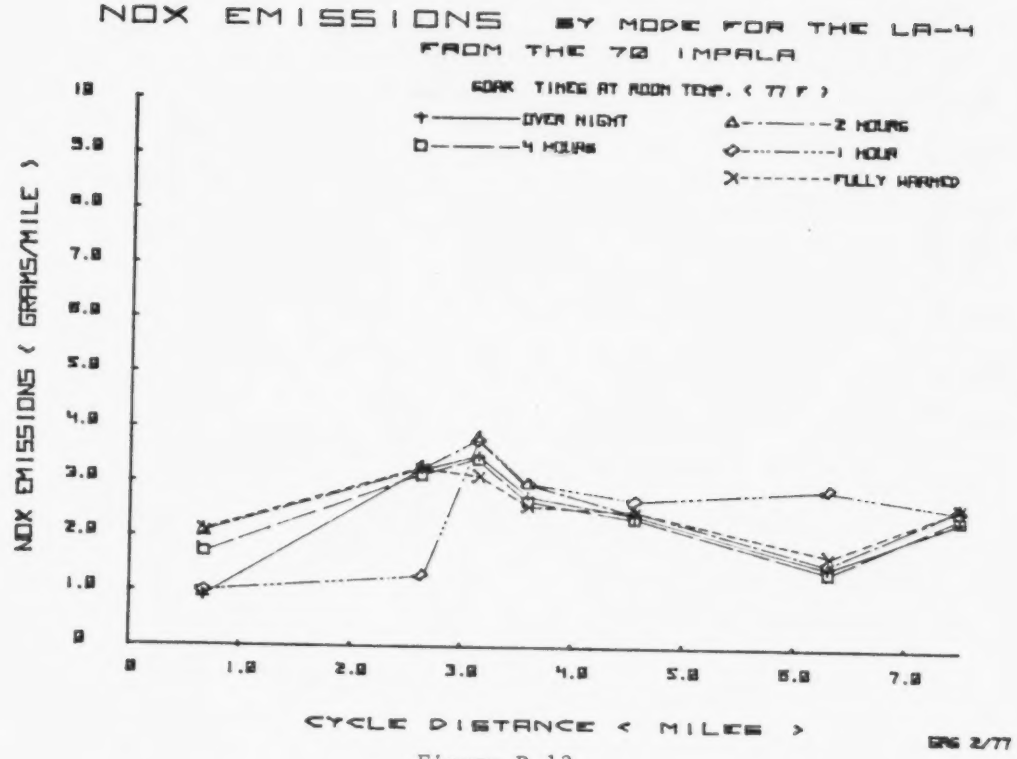

NOX EMISSIONS BY MODE FOR THE N Y C
FROM THE 70 VALIANT
SOAK TIMES AT ROOM TEMP. (77 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
ERS 2/77

Figure D-12

Appendix D



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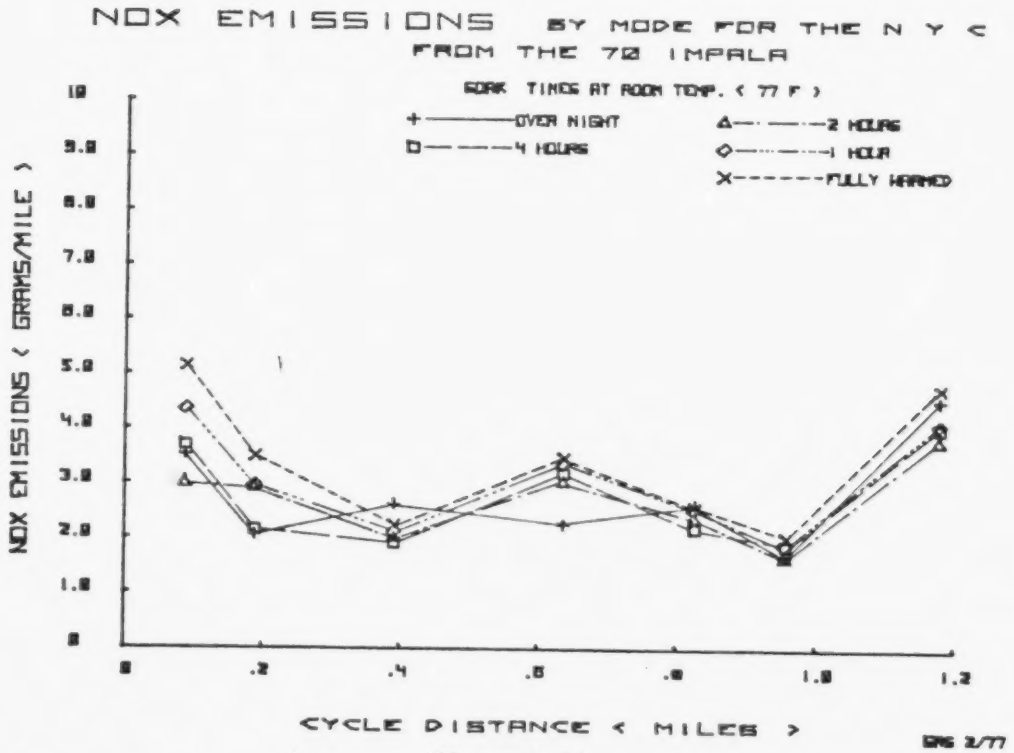

Figure D-14

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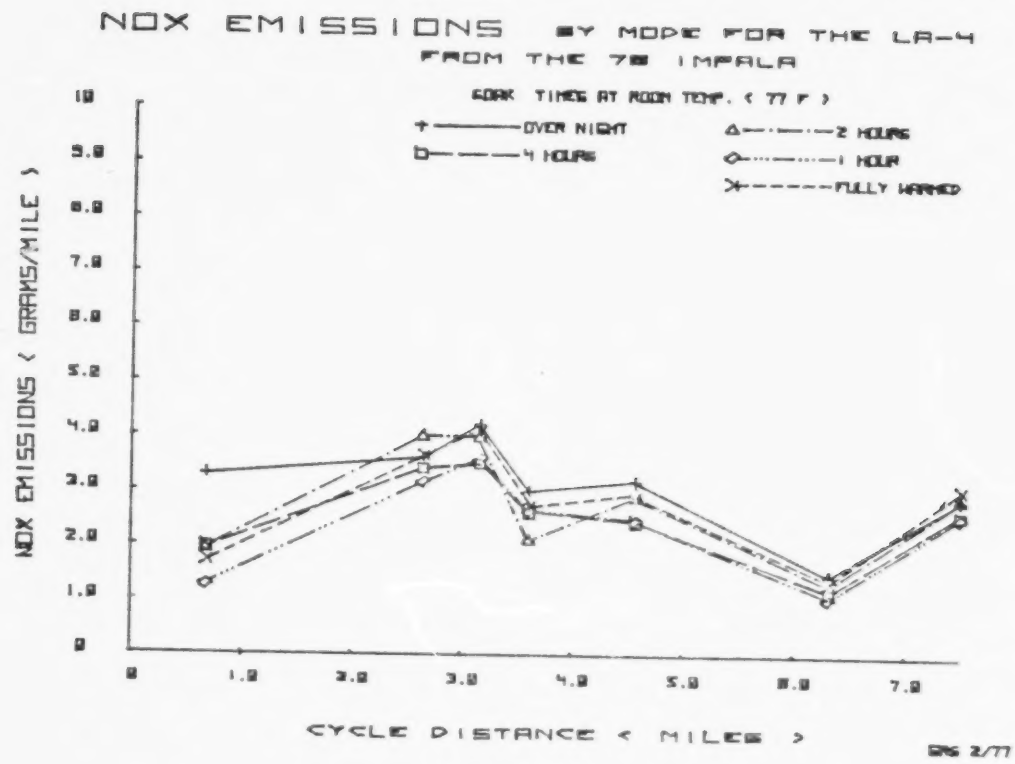

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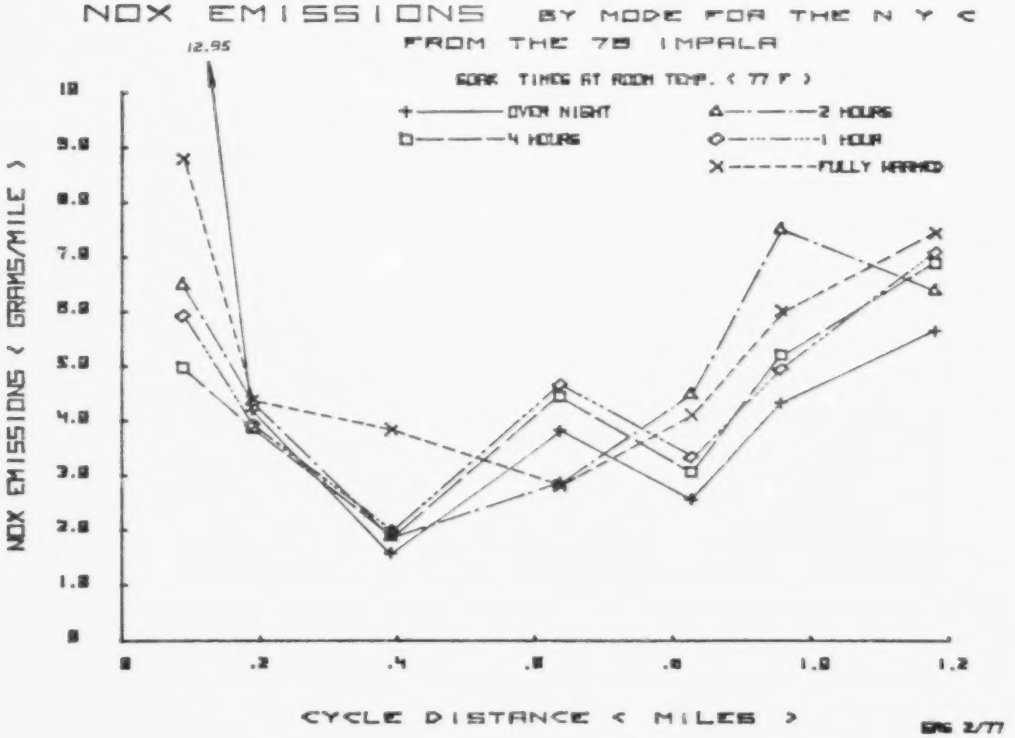

Figure D-16

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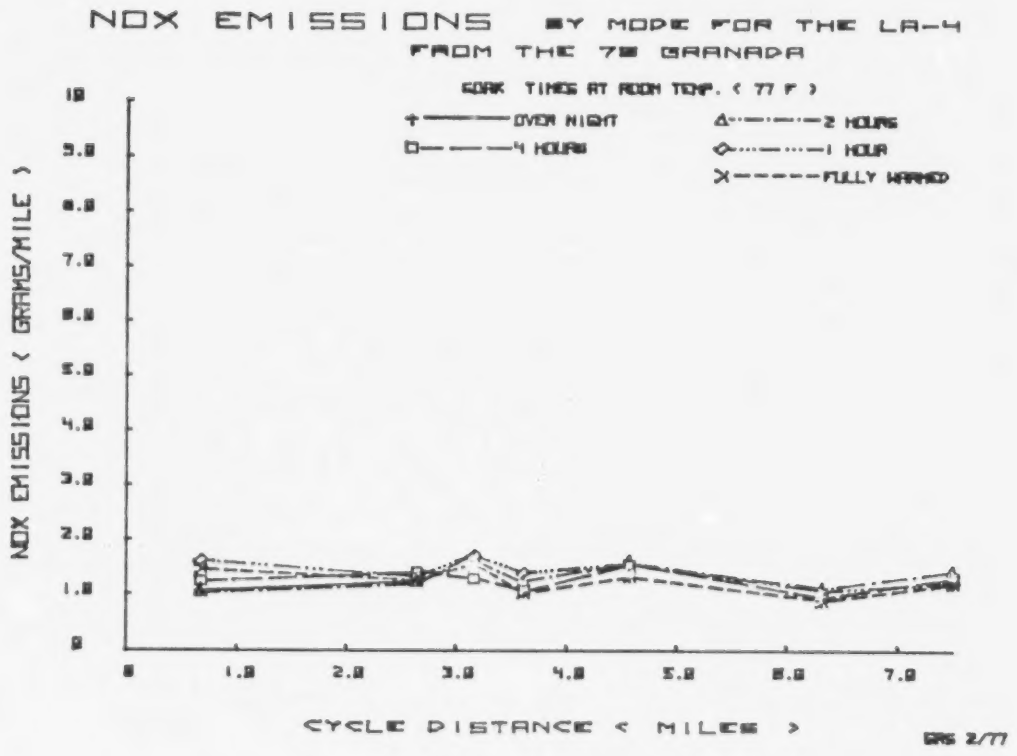

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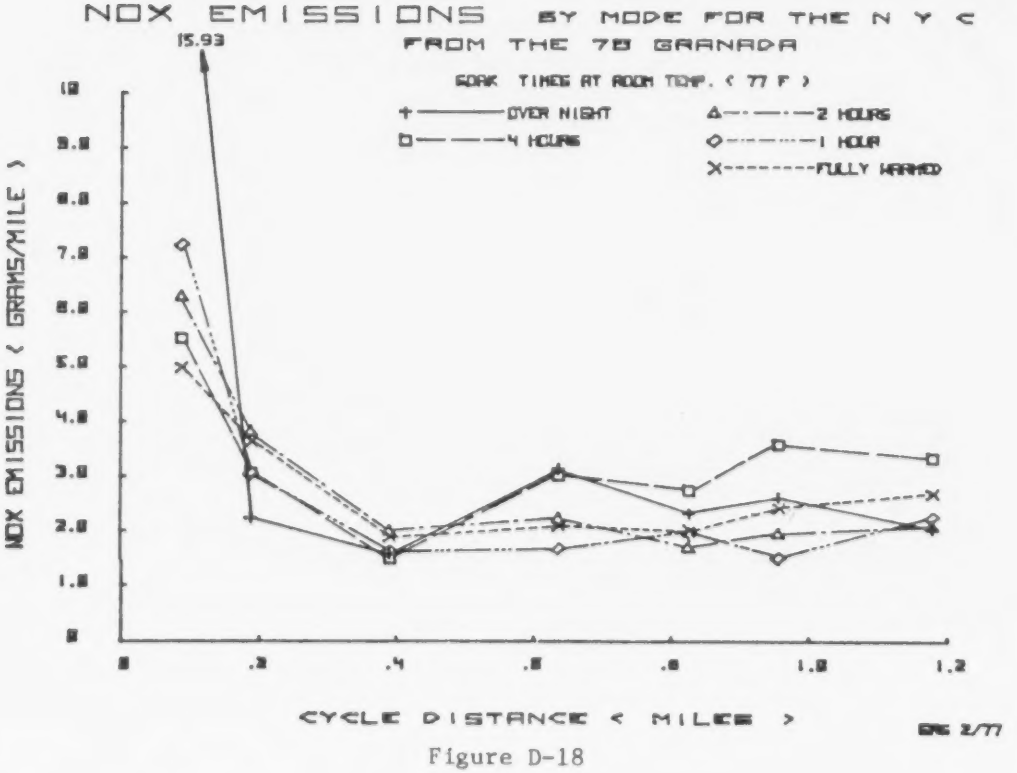

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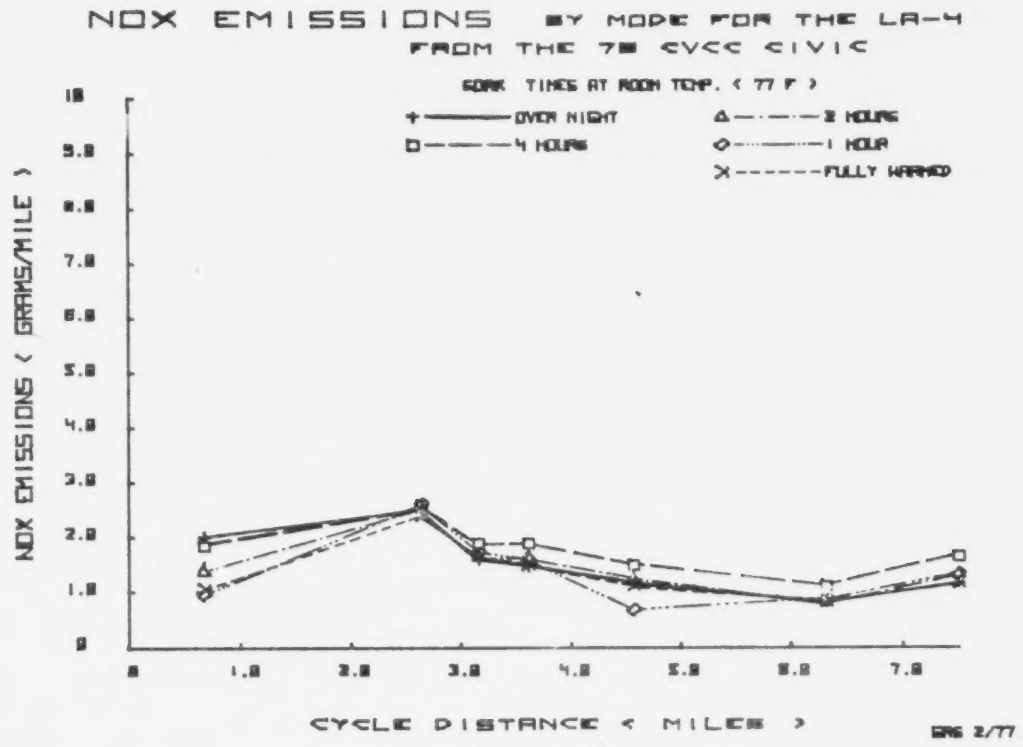

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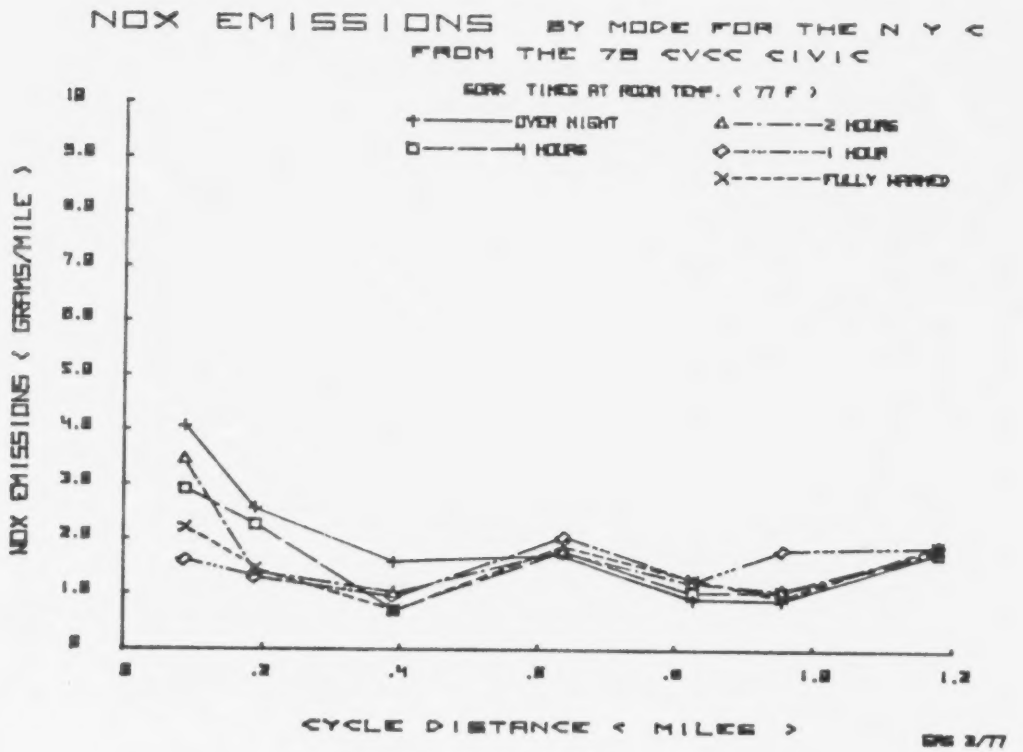
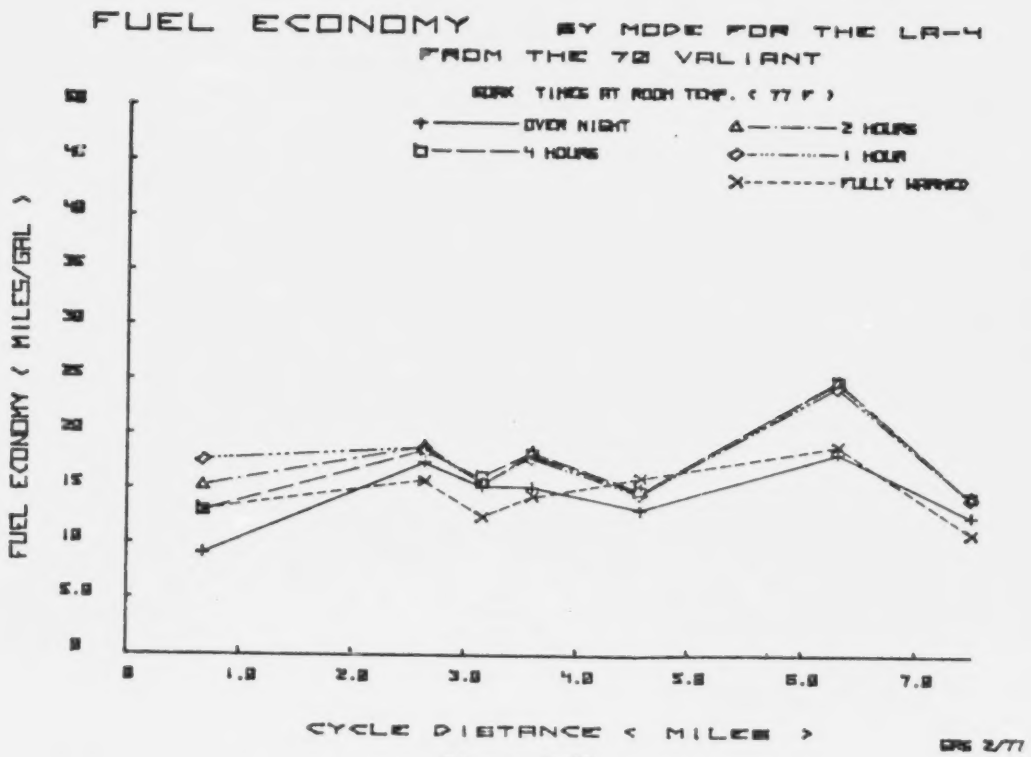

NOX EMISSIONS BY MODE FOR THE N Y C
FROM THE 78 CVCC CIVIC
SOAK TIMES AT ROOM TEMP. (77 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
EMS 2/77

Figure D-20

Appendix D



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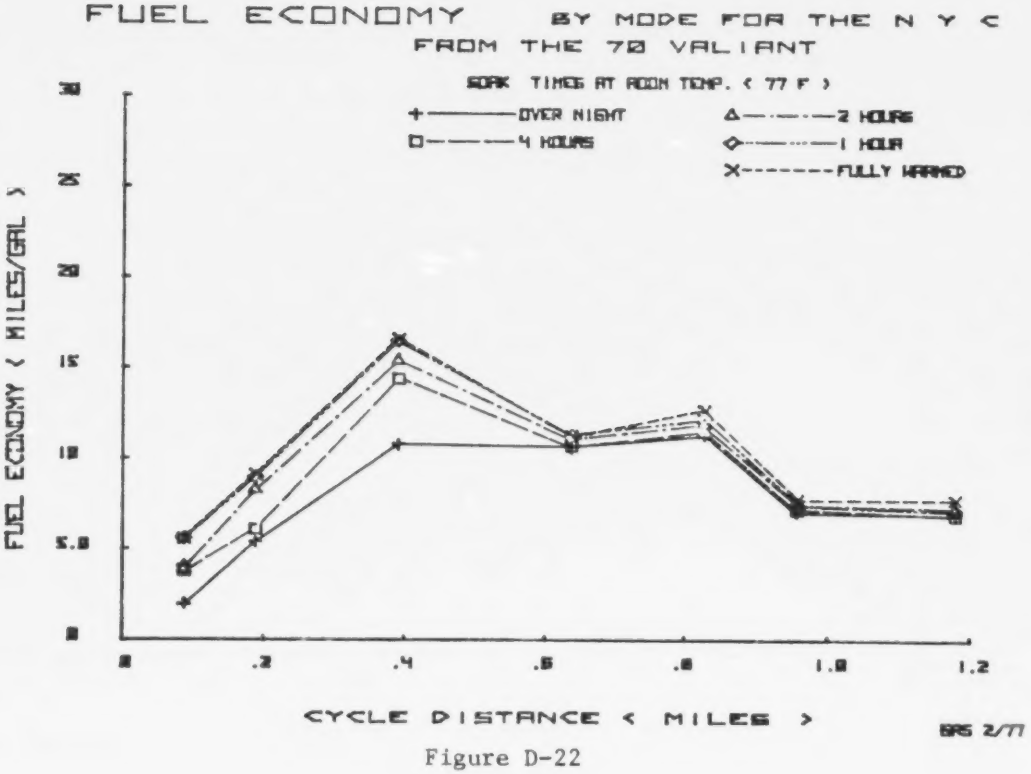

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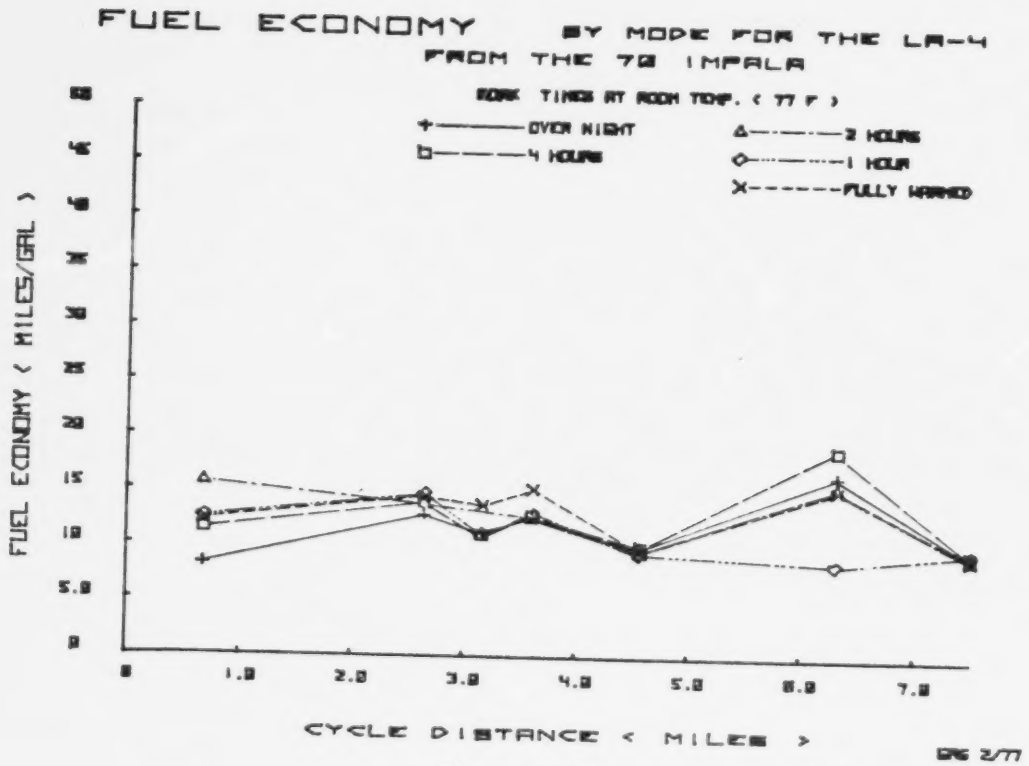

FUEL ECONOMY BY MODE FOR THE LA-4
FROM THE 70 IMPALA
SOAK TIMES AT ROOM TEMP. (77 F)
+——— OVER NIGHT
Δ———— 2 HOURS
□———— 4 HOURS
◇———— 1 HOUR
X------ FULLY WARMED
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
DS 2/77

Figure D-23

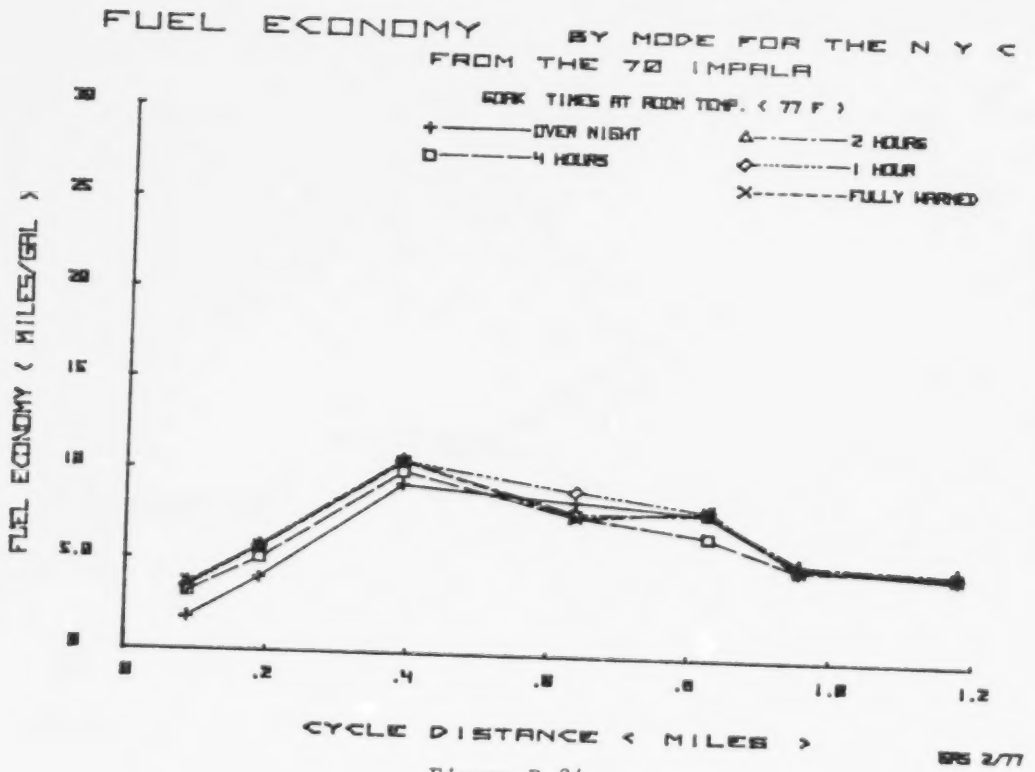
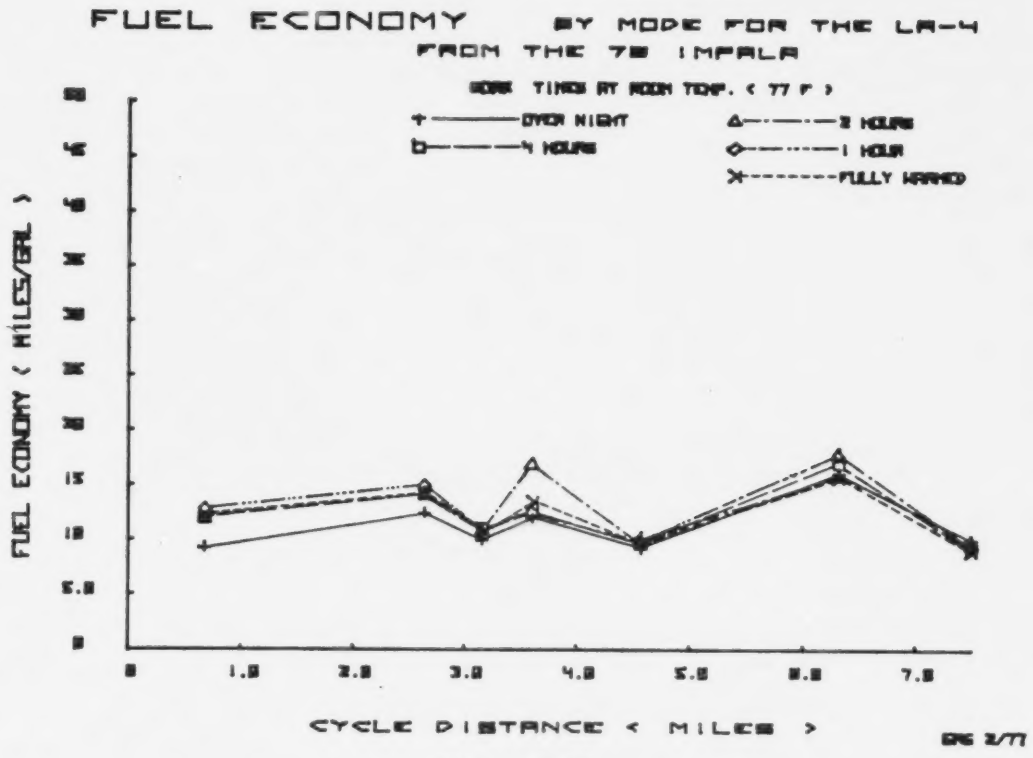

FUEL ECONOMY BY MODE FOR THE N Y C
FROM THE 70 IMPALA
SOAK TIMES AT ROOM TEMP. (77 F)
+——— OVER NIGHT
Δ———— 2 HOURS
□———— 4 HOURS
◇———— 1 HOUR
X------- FULLY WARMED
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
DS 2/77

Figure D-24

Appendix D



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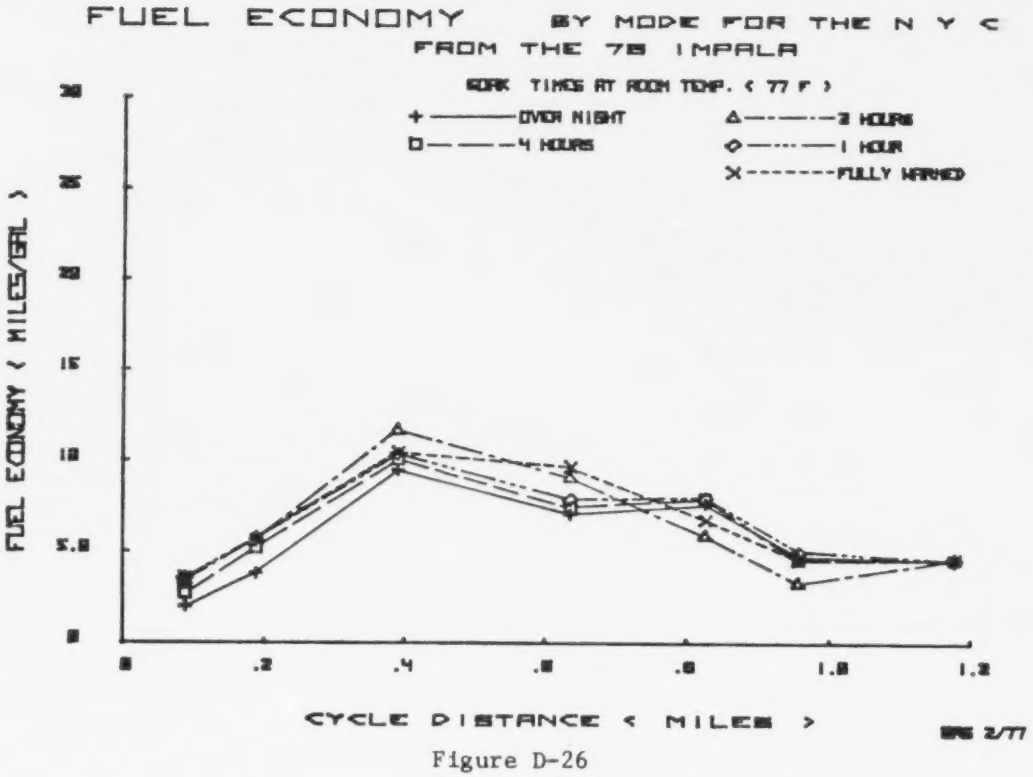
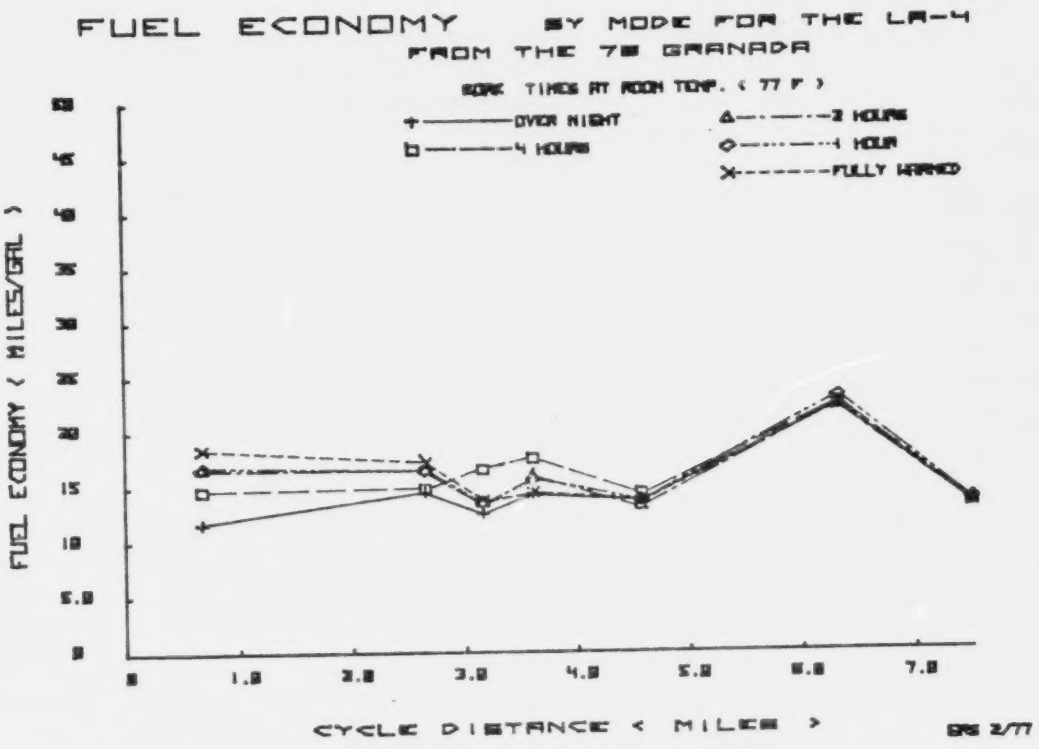


Figure D-26

Appendix D



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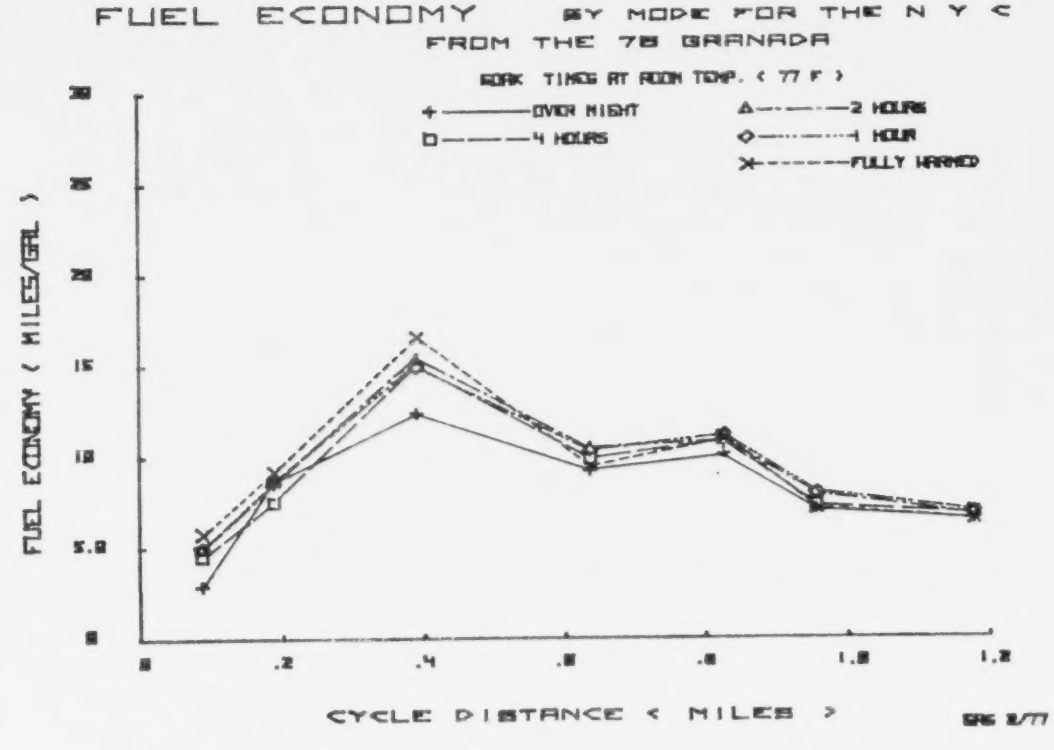
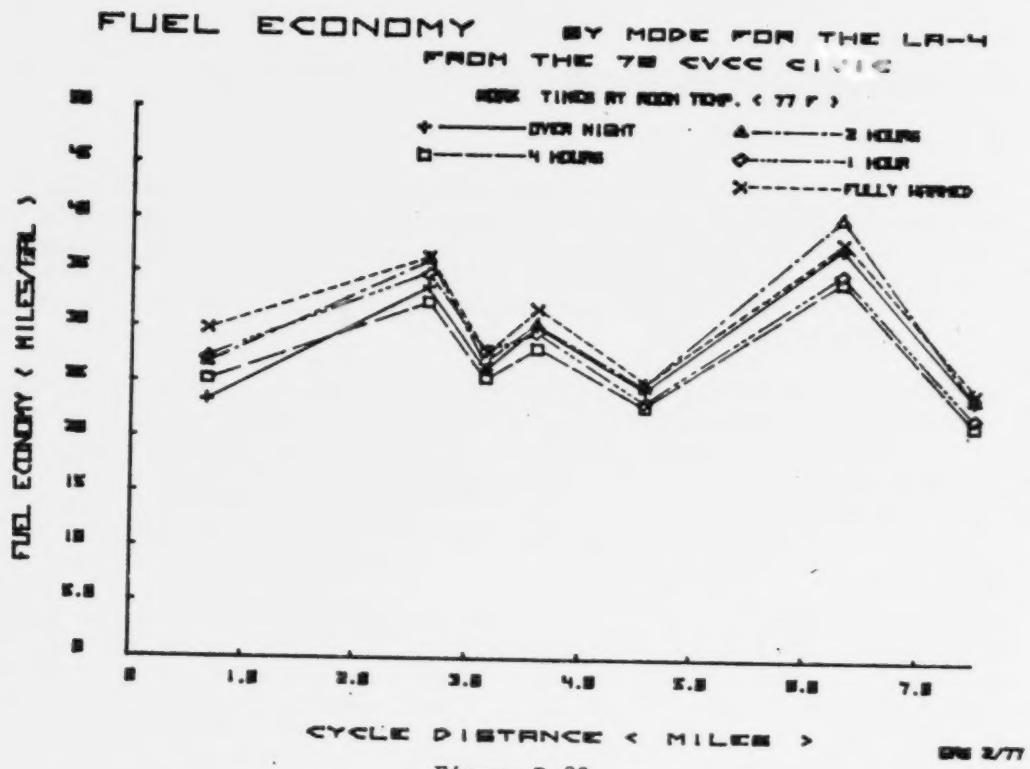

FUEL ECONOMY BY MODE FOR THE N Y C
FROM THE 78 GRANADA
SOAK TIMES AT ROOM TEMP. (77 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
DS 2/77

Figure D-28

Appendix D



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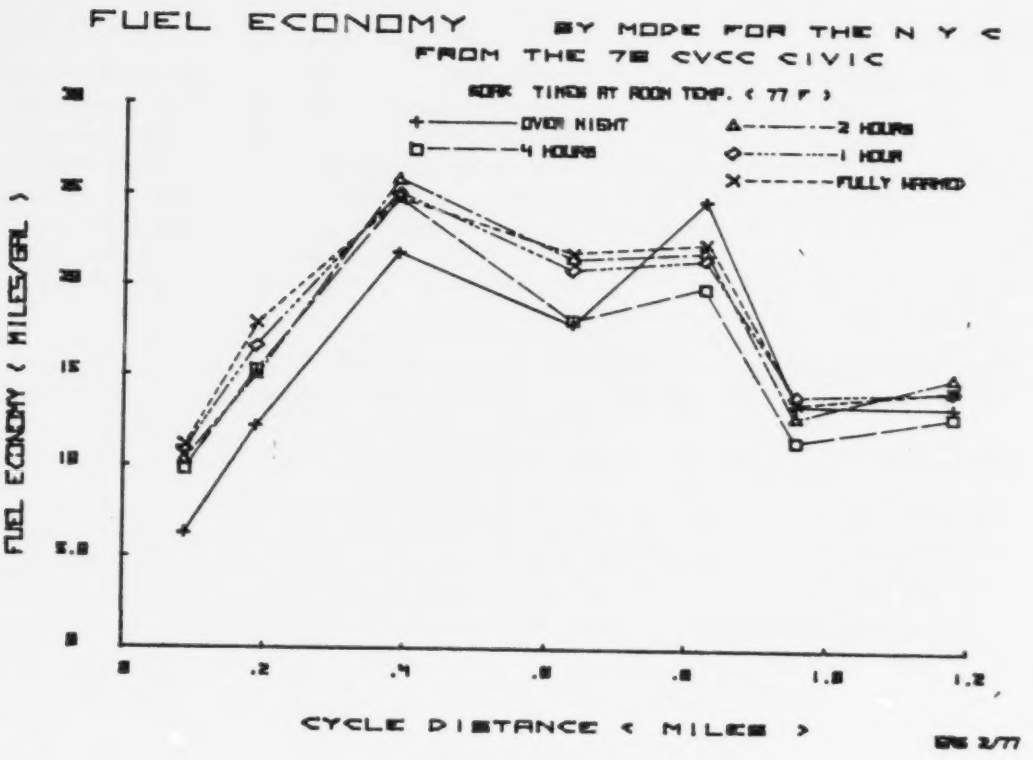
FUEL ECONOMY BY MODE FOR THE N Y C
FROM THE 78 CVCC CIVIC
SOAK TIMES AT ROOM TEMP. (77 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
EMS 2/77

Figure D-30

Appendix E

Cold start from outside ambient (10-25°F) all vehicles.

HC Emissions Figures E-1 and E-2

The mode 1 HC emissions of both driving cycles increased substantially with the 10-25°F soak temperature. Compared to the cold starts from room temperature, the mode 1 HC emissions increased by factors ranging from 2.5 to 9.5. This is roughly the same range of factors demonstrated by the mode 1 CO emissions comparing the cold start at 10-25°F to that at room temperature.

The range of the HC emissions from the highest emitting vehicle to that of the lowest increased from 1.5 for mode 1 after room temperature soak to 3.5 following the soak at 10-25°F. This increase was due primarily to the pre-control cars. The three 1976 model cars mode 1 HC emissions are within a factor of 2.0 for the '75 FTP and approximately 1.4 for the NYC. The NYC HC emissions remained approximately 5 times those of the '75 FTP.

The overall effect of soak temperature on the NYC and the '75 FTP Bag and Composite HC emissions levels is shown in Table E-1. As with the CO emissions (see Table 2) there was a large increase in NYC and '75 FTP HC emissions between the 77°F and 10-25°F soak temperatures. The increase in the '75 FTP was entirely due to the Bag 1 emissions which increased by factors ranging from 3.4 to 5.2. The NYC, being closer in length to the '75 FTP Bag 1 increased by factors similar to those of Bag 1.

NOx Emissions Figures E-3 and E-4

The NOx emissions following the 10-25°F soak were very similar to those following the room temperature soak. That is, the effect of the cold start on the NOx emission levels was of the same order of magnitude as the effects produced by mode-to-mode differences in the driving cycles. The notable exceptions were the mode 1 NOx emissions for the '76 Impala and '76 Granada, which were higher for the NYC following the room temperature soak. Following the overnight soak at 10-25°F these two cars did not have high mode 1 NOx emissions for the NYC, but more closely resembled the other vehicles emissions.

Table E-2 shows that the overall effects of the different soak temperatures on the '75 FTP and the NYC NOx emissions are small.

Fuel Economy Figures E-5 and E-6

The loss of mode 1 fuel economy following the 10-25°F soak was more noticable than that following the 77°F soak. Still, the magnitude of these changes was modest. Comparing the 10 to 25°F soaked '75 FTP Bag 1 and NYC fuel economies to those for the fully warmed vehicle, we see fuel economy decreases in the range of 40 to 120%. (See Table E-3).

Appendix E

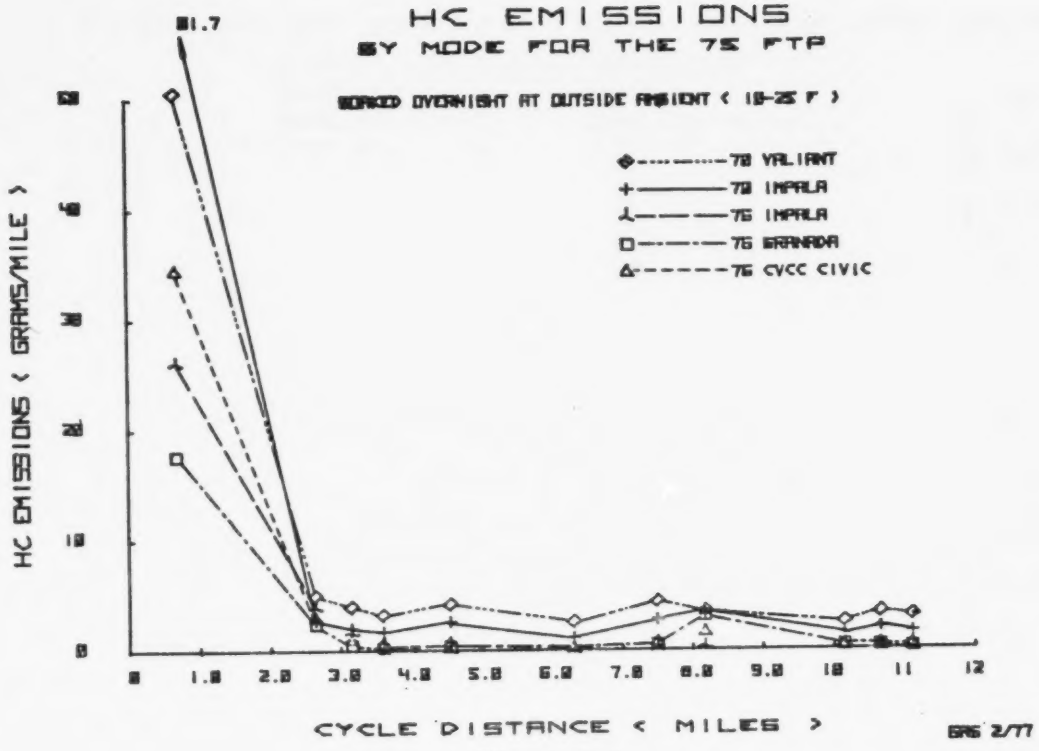

Figure E-1

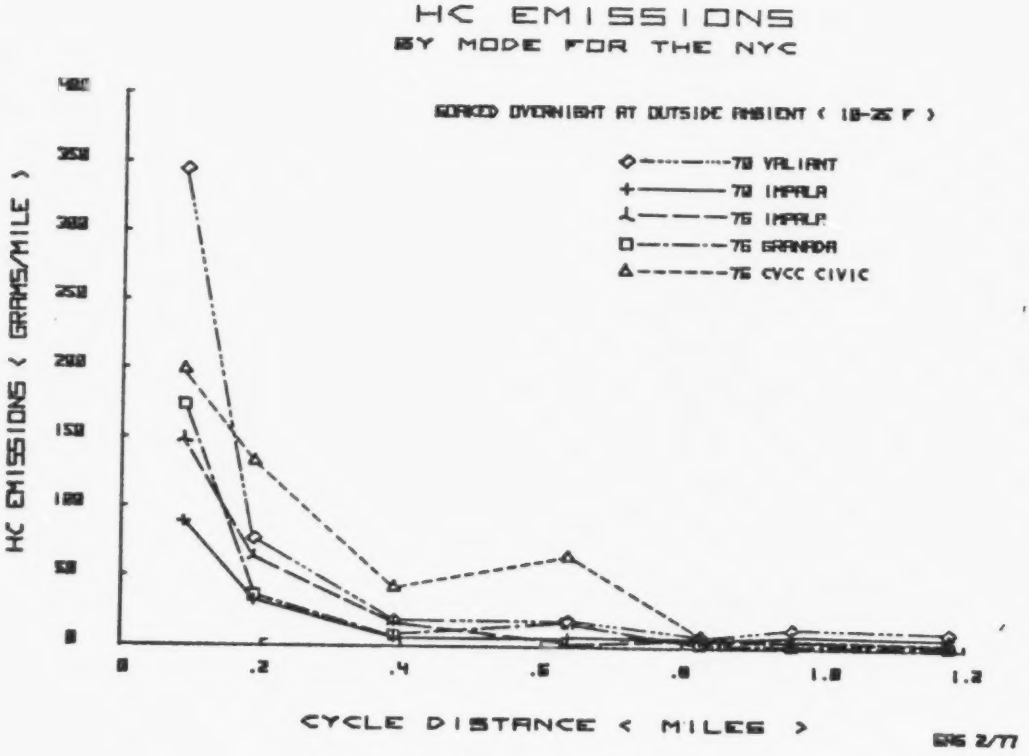

Figure E-2

Appendix E

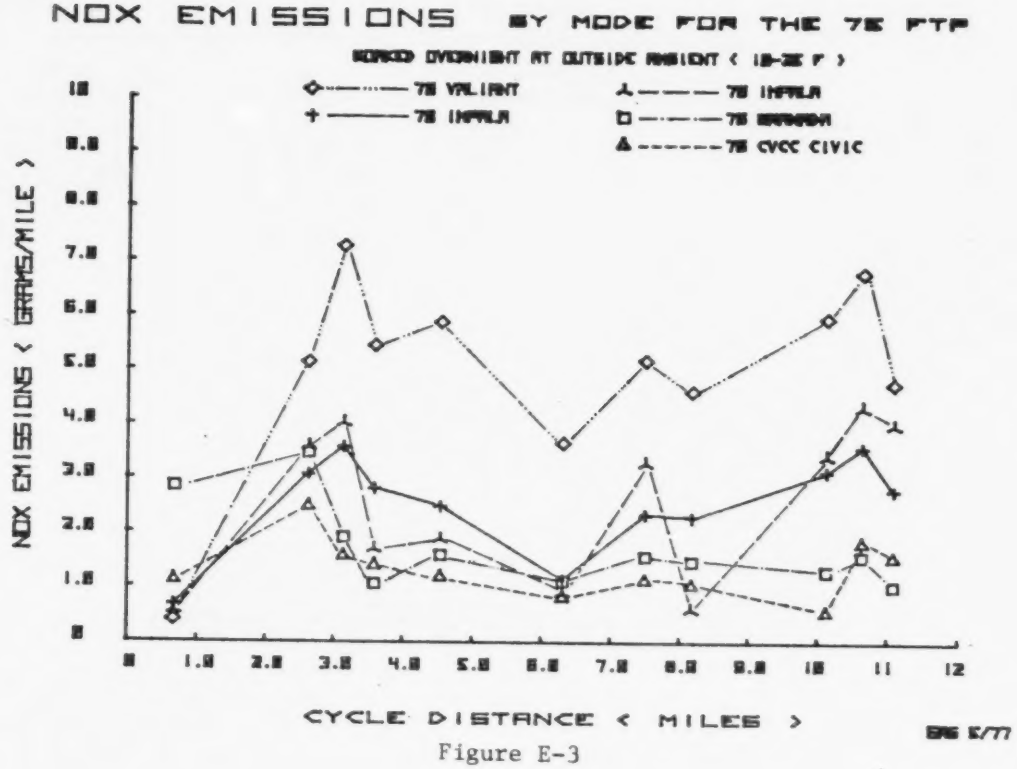
NOX EMISSIONS BY MODE FOR THE 75 FTP
SOAKED OVERNIGHT AT OUTSIDE AMBIENT (10-25 F)
75 VALIANT
75 IMPALA
75 IMPALA
75 CVCC CIVIC
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)

Figure E-3

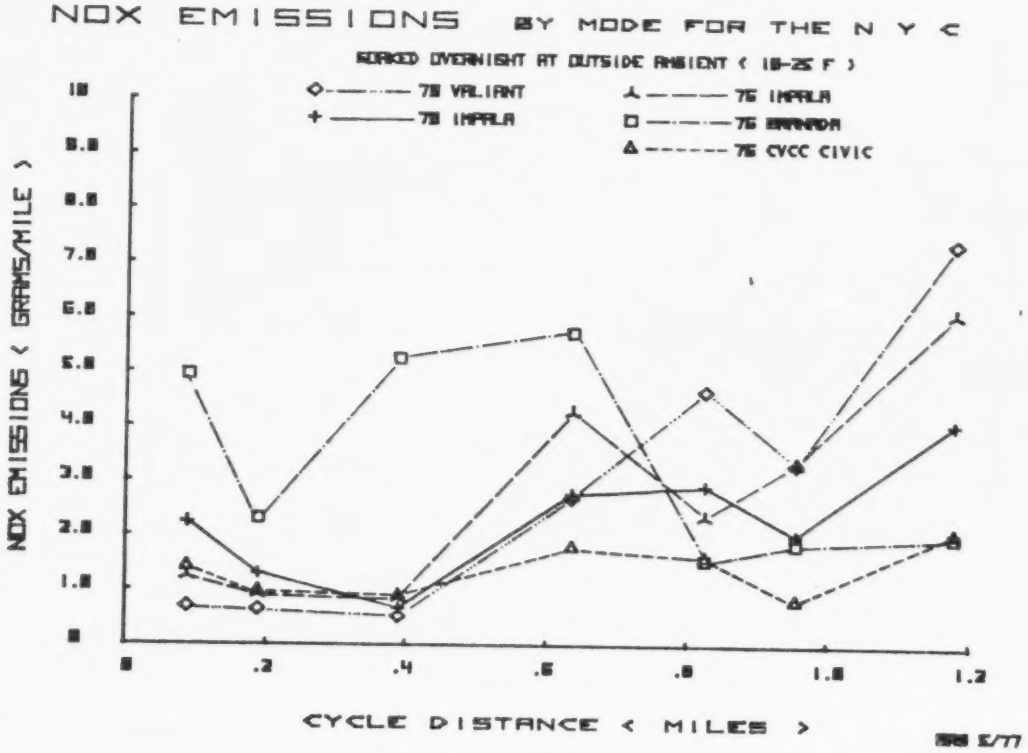
NOX EMISSIONS BY MODE FOR THE N Y C
SOAKED OVERNIGHT AT OUTSIDE AMBIENT (10-25 F)
75 VALIANT
75 IMPALA
75 IMPALA
75 CVCC CIVIC
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)

Figure E-4

Appendix E

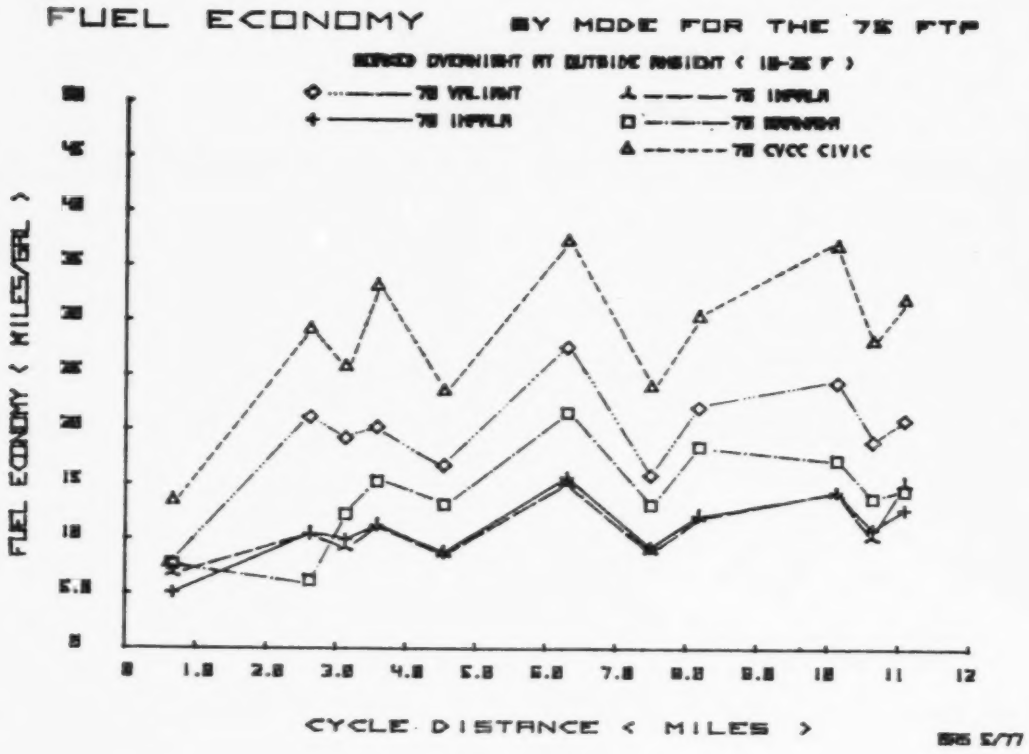
FUEL ECONOMY BY MODE FOR THE 75 FTP
SOAKED OVERNIGHT AT OUTSIDE AMBIENT (10-25 F)
78 VALIANT
78 IMPALA
75 IMPALA
75 CVCC CIVIC
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)

Figure E-5

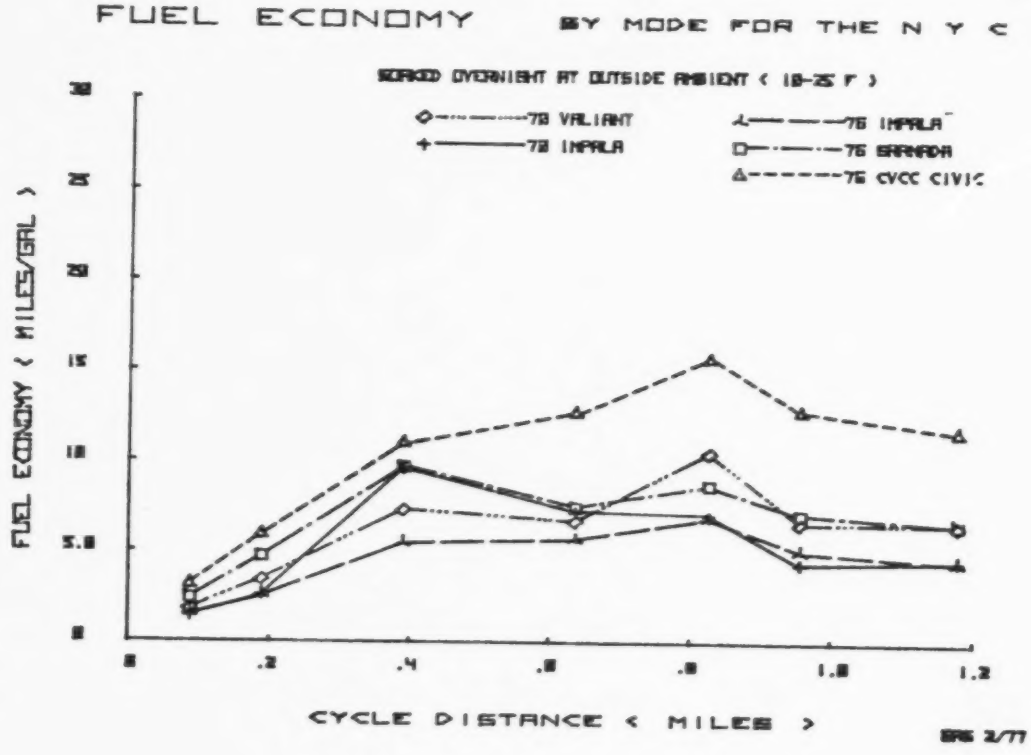
FUEL ECONOMY BY MODE FOR THE N Y C
SOAKED OVERNIGHT AT OUTSIDE AMBIENT (10-25 F)
78 VALIANT
78 IMPALA
75 IMPALA
75 CVCC CIVIC
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)

Figure E-6

Table E-1

HC Emissions in Grams/Mile

Vehicles Fully Warmed

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	2.2	1.7	0.2	0.6	0.5
Bag 1	2.2	1.5	0.4	0.9	0.6
Bag 2	2.3	1.9	0.1	0.3	0.4
NYC	6.3	4.8	0.7	0.7	1.8

Vehicles Soaked Overnight at Room Temp. (Approx. 77°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	6.6	1.9	0.6	0.7	0.7
Bag 1	13.8	2.6	1.9	1.4	1.7
Bag 2	6.2	1.8	0.1	0.4	0.4
Bag 3	2.2	1.5	0.4	0.9	0.6
NYC	13.9	2.8	4.6	2.9	6.9

Vehicles Soaked Overnight at Outside Ambient (10-25°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	6.3	4.3	1.7	1.4	2.1
Bag 1	13.3	13.7	7.4	4.7	8.3
Bag 2	3.5	2.0	0.1	0.4	0.4
Bag 3	6.5	1.8	0.4	0.9	0.6
NYC	44.0	15.0	21.6	21.5	66.8

Table E-2

NOx Emissions in Grams/Mile

Vehicles Fully Warmed

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	4.9	2.5	2.7	1.2	1.5
Bag 1	5.6	3.0	3.3	1.3	1.9
Bag 2	4.3	2.2	2.3	1.1	1.0
NYC	5.9	3.3	5.0	2.6	1.5

Vehicles Soaked Overnight at Room Temp. (Approx. 77°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	4.9	2.4	2.8	1.2	1.3
Bag 1	5.0	2.8	3.6	1.2	2.2
Bag 2	4.4	2.0	2.3	1.1	0.7
Bag 3	5.6	3.0	3.3	1.3	1.9
NYC	4.0	3.3	3.6	3.4	1.7

Vehicles Soaked Overnight at Outside Ambient (10-25°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	4.4	2.4	2.0	1.7	1.2
Bag 1	4.6	2.8	2.8	2.8	2.0
Bag 2	4.6	2.0	1.8	1.4	1.0
Bag 3	3.7	3.0	1.4	1.3	1.0
NYC	3.3	2.9	3.1	3.5	1.7

Table E-3

Fuel Economy in Miles/Gallon

Vehicles Fully Warmed

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	18.0	12.6	12.2	16.5	31.1
Bag 1	22.4	14.0	13.5	16.4	32.9
Bag 2	15.2	11.5	11.4	16.6	29.6
NYC	9.8	6.2	6.2	8.8	17.7

Vehicles Soaked Overnight at Room Temp. (Approx. 77°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	16.3	12.4	12.0	15.8	30.0
Bag 1	14.3	11.4	11.2	13.5	29.5
Bag 2	15.0	12.0	11.9	16.6	28.9
Bag 3	22.4	14.0	13.1	16.4	32.9
NYC	6.8	5.3	5.2	7.6	14.9

Vehicles Soaked Overnight at Outside Ambient (10-25°F)

Test Cycle	'70 Valiant	'70 Impala	'76 Impala	'76 Granada	'76 CVCC Civic
'75 FTP	19.5	11.0	11.2	13.1	28.5
Bag 1	15.6	8.7	9.5	7.5	23.7
Bag 2	20.1	11.3	11.1	16.1	28.6
Bag 3	22.4	13.1	13.2	16.4	33.2
NYC	5.5	4.5	4.3	6.4	9.5

Appendix F

Varying Soak Times at Outside Ambient (10-25°F)

HC Emissions Figures F-1 through F-10

Again there is much similarity between the CO and HC emission curves at varying soak times at 10-25°F. The most notable difference was that the HC emissions took less time to decay to fully warmed values. The HC emissions had very largely decayed after 125 seconds for the LA-4 and after 195 to 274 seconds for the NYC.

Comparing the HC emissions with varying soak times for the two different soak temperatures we again see similarities with the CO curves. That is, that a 4 hour soak at 10-25°F results in higher mode 1 HC emissions than an overnight soak at 77°F.

NOx Emissions Figures F-11 through F-20

The effect of varying soak time at 10-25°F on NOx emissions was difficult to determine because of the variability of the data. The more noticable mode 1 changes occurred on the NYC.

Fuel Economy Figures F-21 through F-30

Fuel economy decay times to fully warmed levels following soaks at 10-25°F were slower than any of these for the emissions. Fully warmed fuel economies were not achieved until 3.59 miles and 505 seconds for the LA-4 and .83 miles and 446 seconds for the NYC. This longer decay time is probably due to the slower warm-up of the transmission (see Figures 27 through 30) and other drive train components.

For the '70 and '76 Impalas, the mode 1 fuel economies following the 4 hour soak were nearly the same as those following an overnight soak. The other vehicle had more evenly spaced increases in mode 1 fuel economy with decreasing soak time.

Appendix F

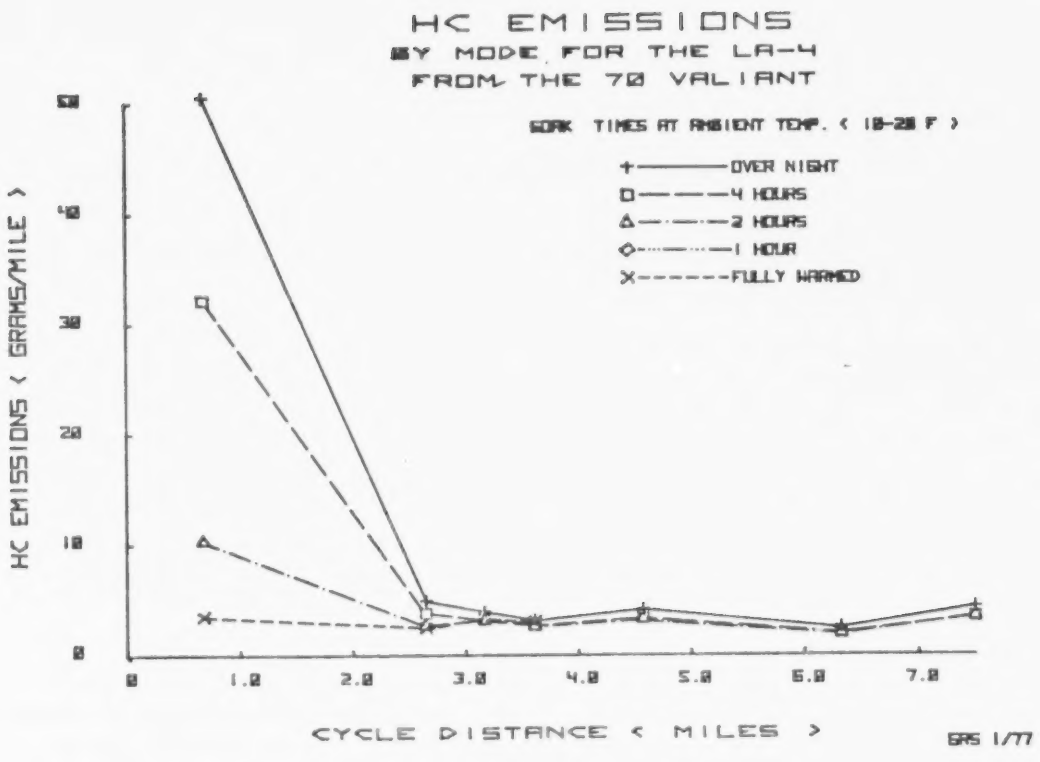

Figure F-1

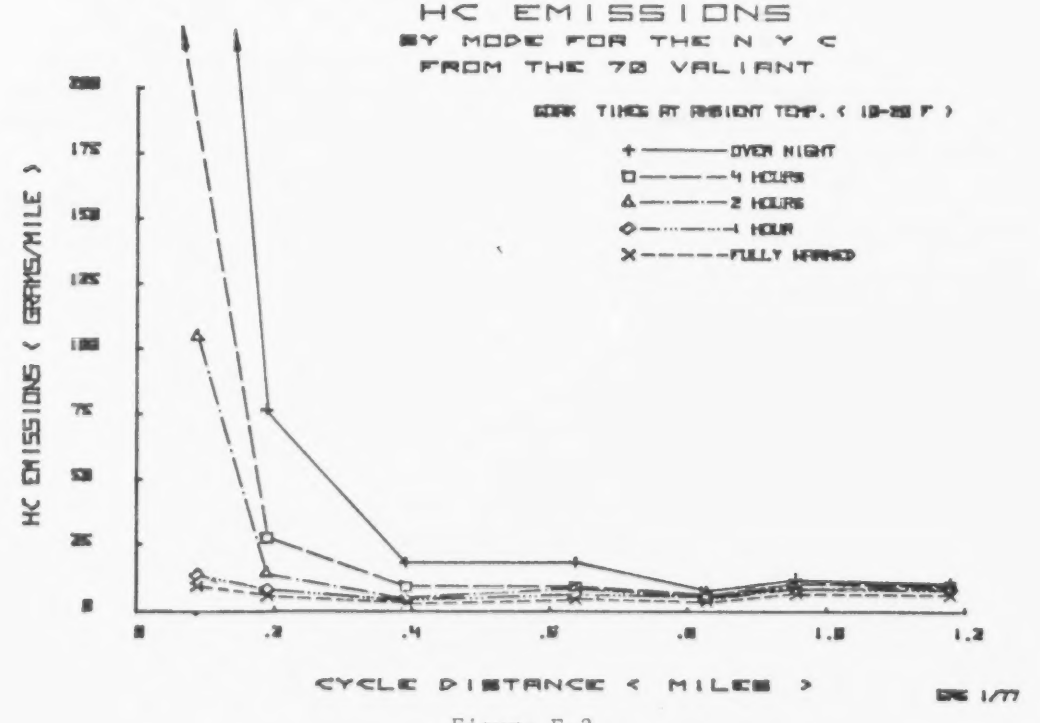

Figure F-2

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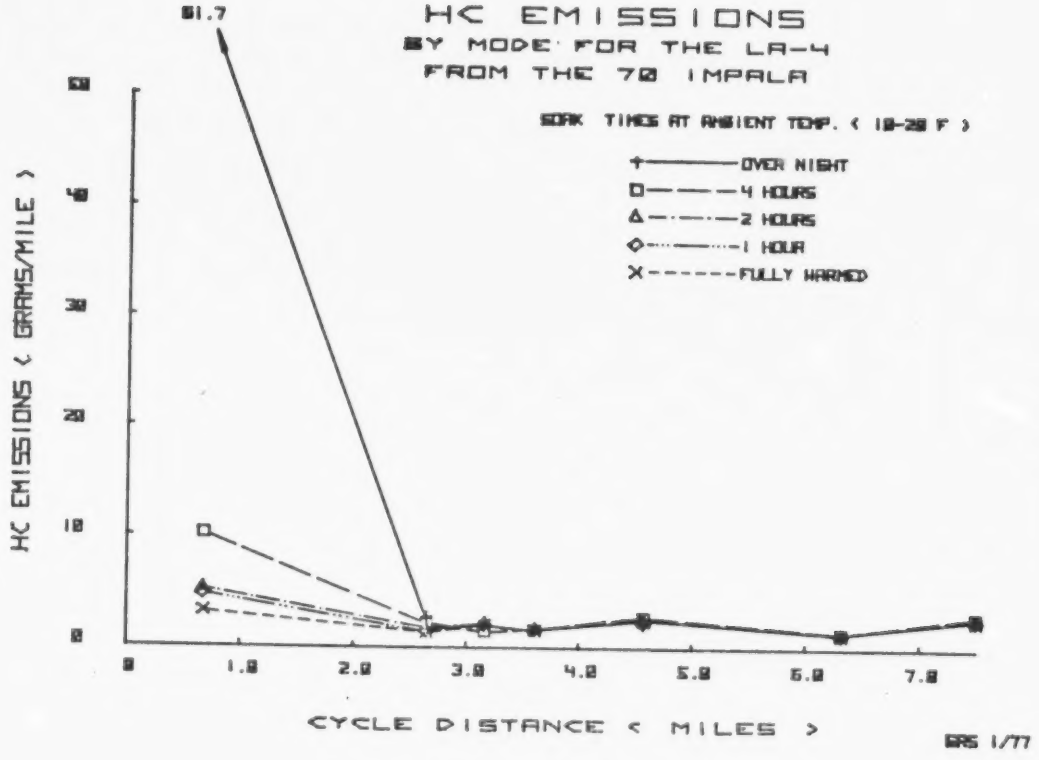

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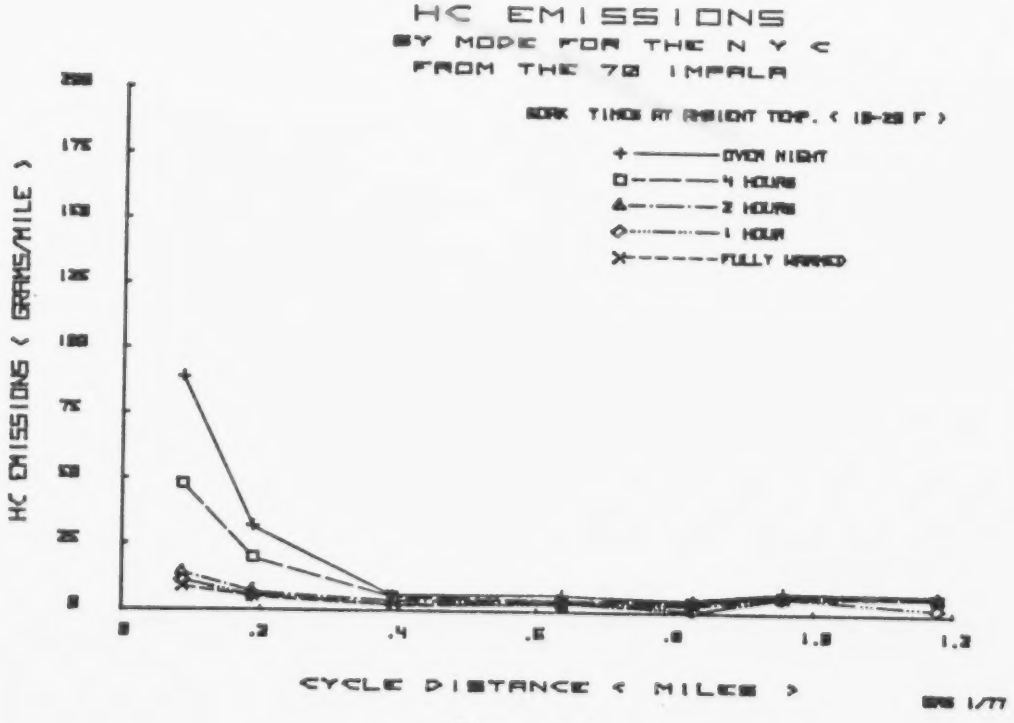
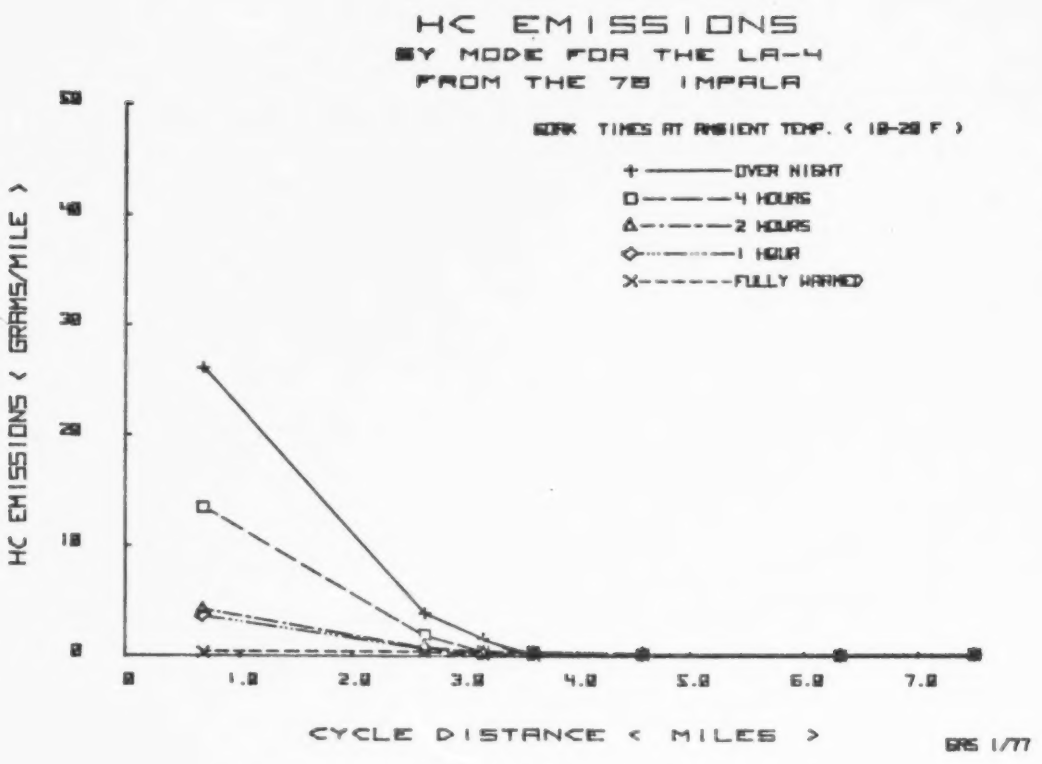


Figure F-4

Appendix F



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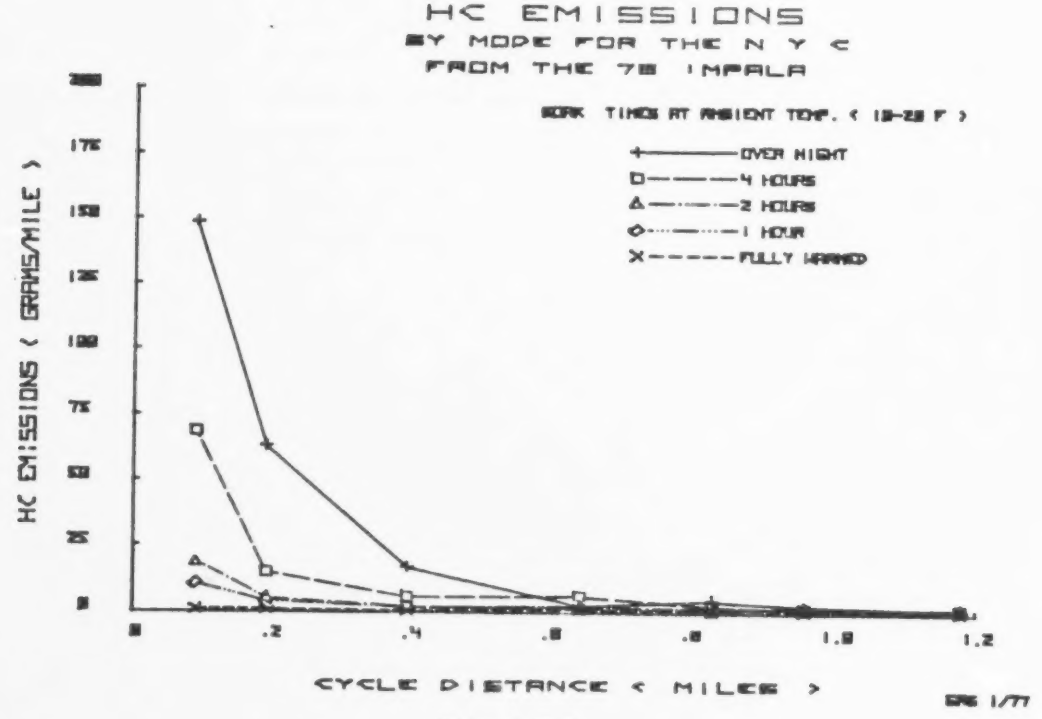

Figure F-6

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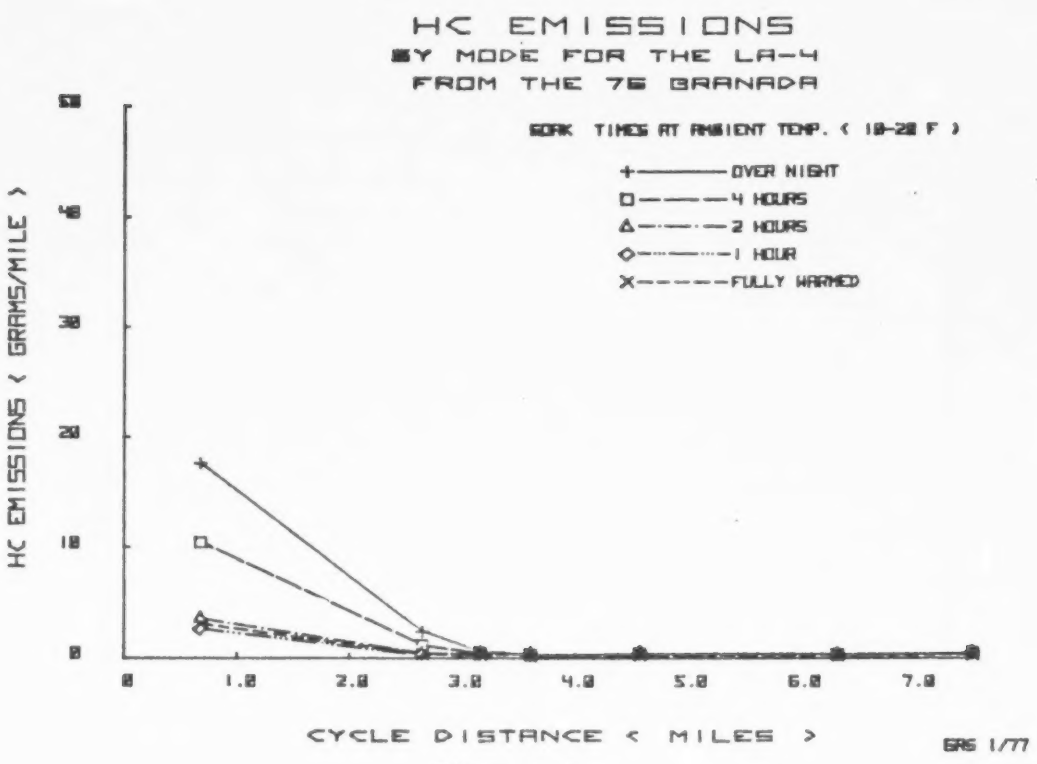

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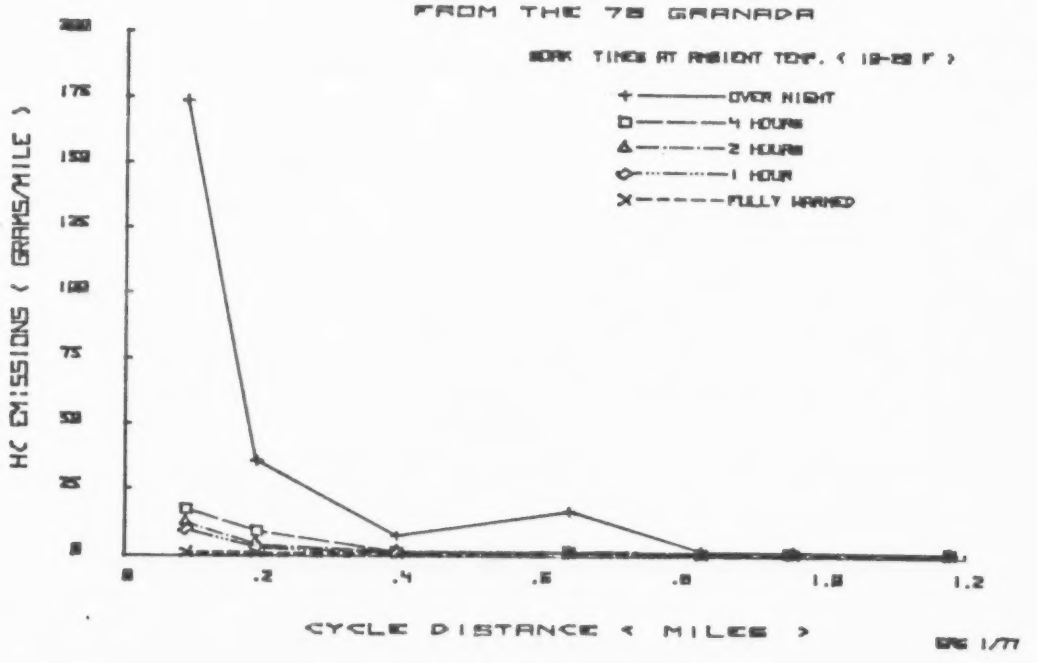

Figure F-8

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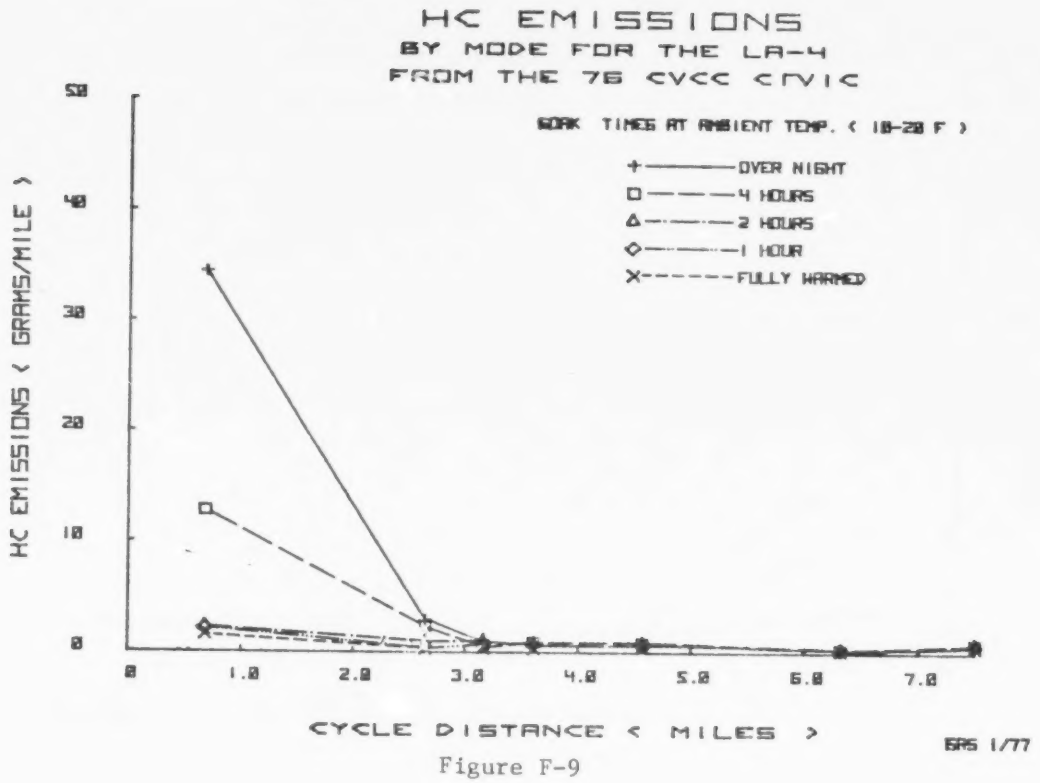

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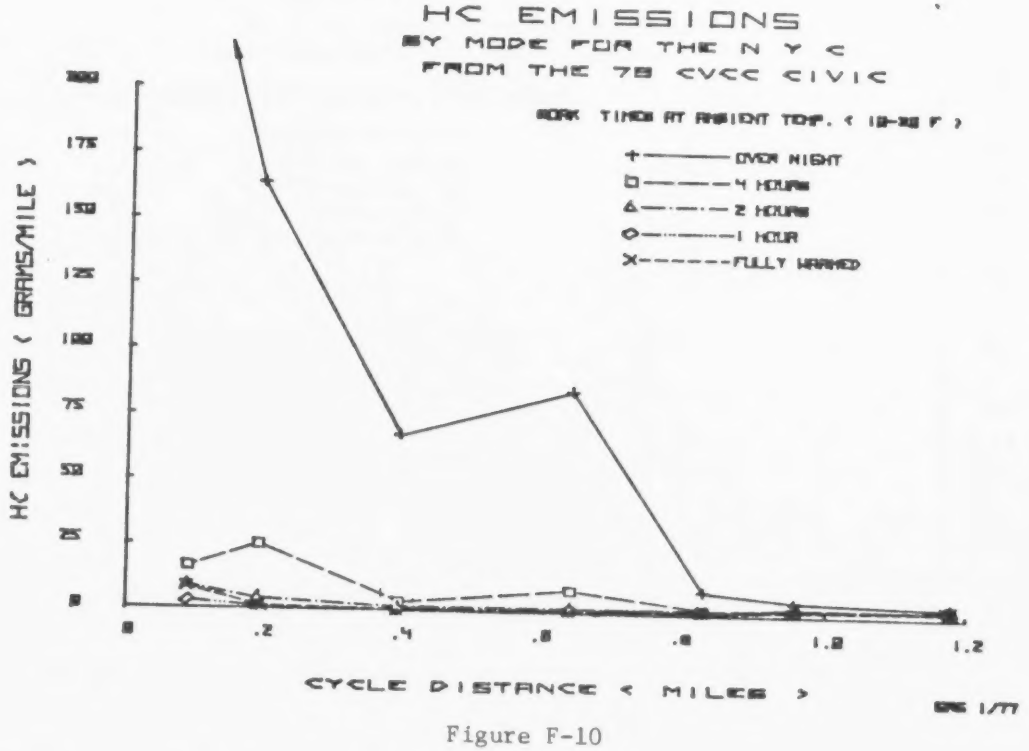

Figure F-10

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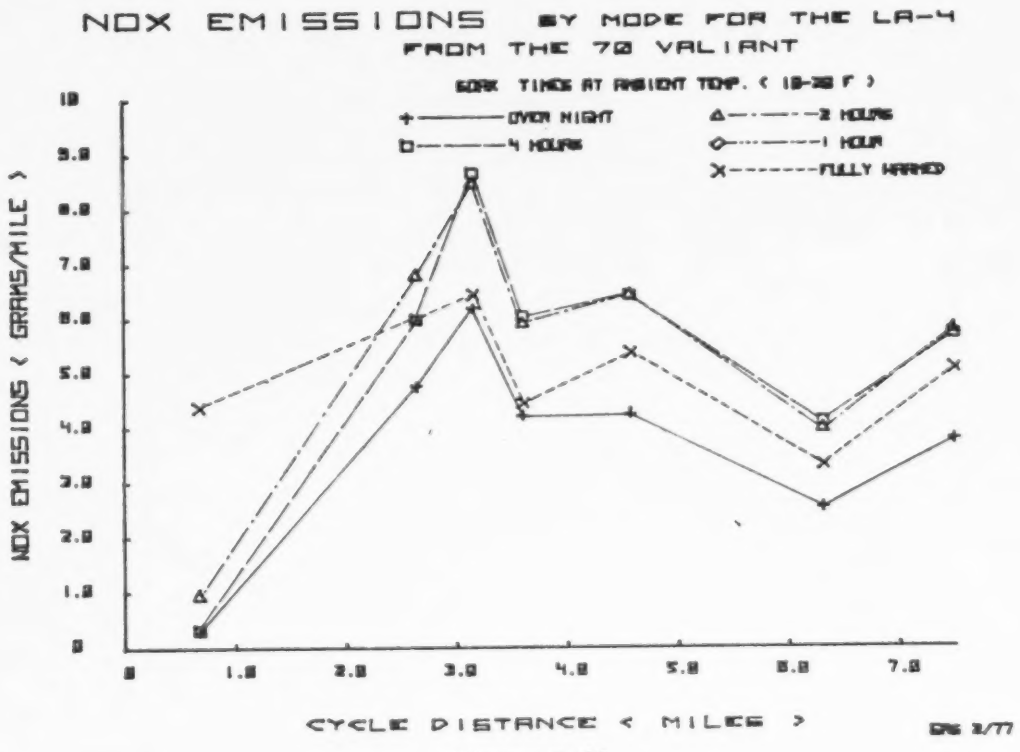

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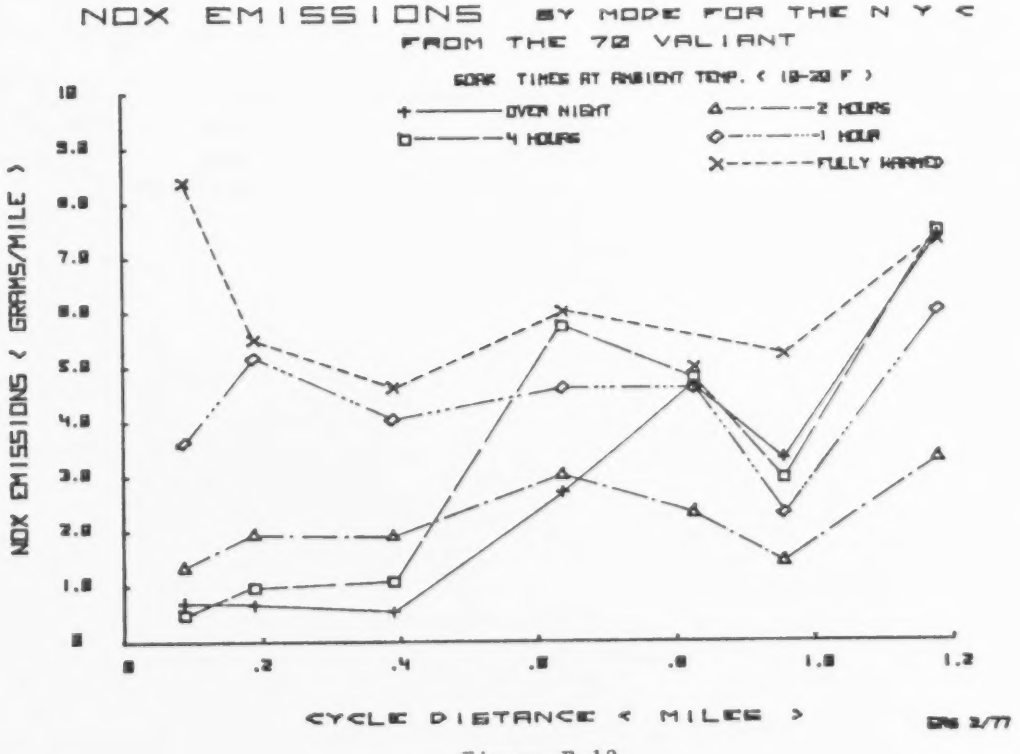
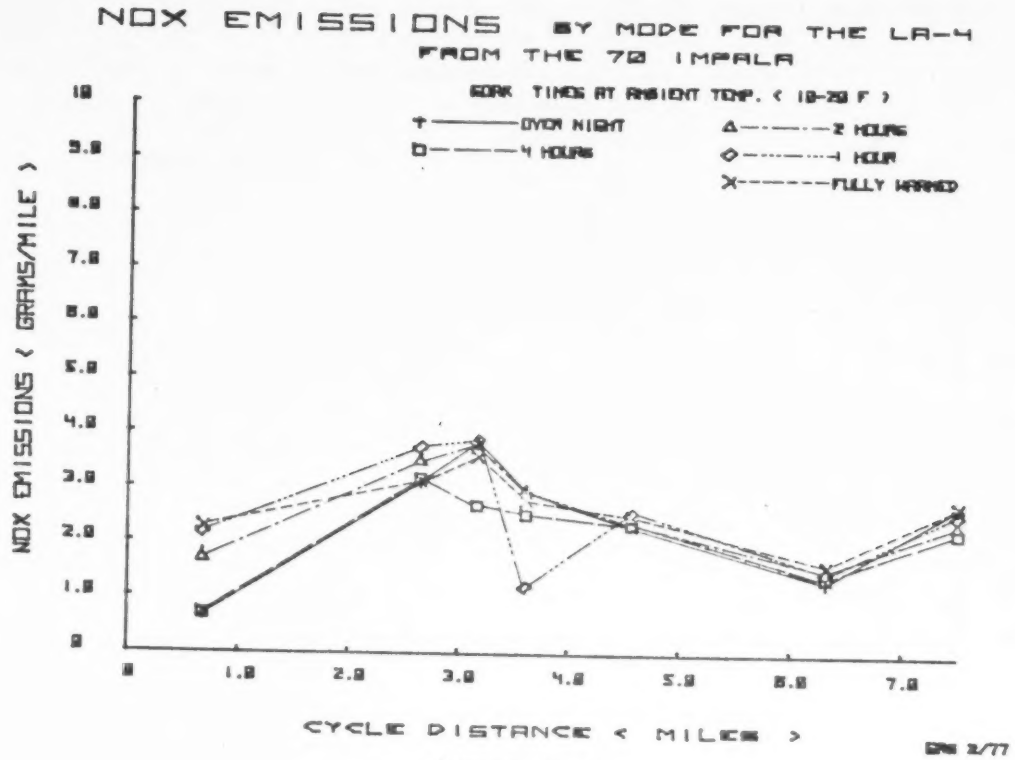

NOX EMISSIONS BY MODE FOR THE N Y C
FROM THE 70 VALIANT
SOAK TIMES AT AMBIENT TEMP. (18-28 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
ENG 2/77

Figure F-12

Appendix F



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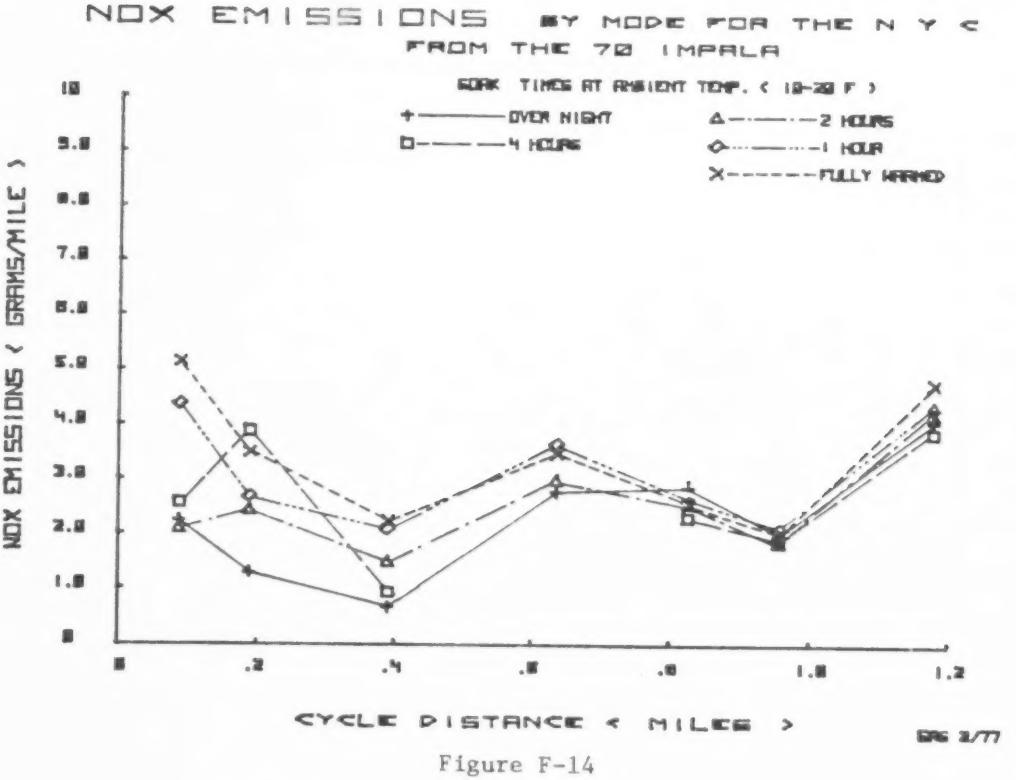
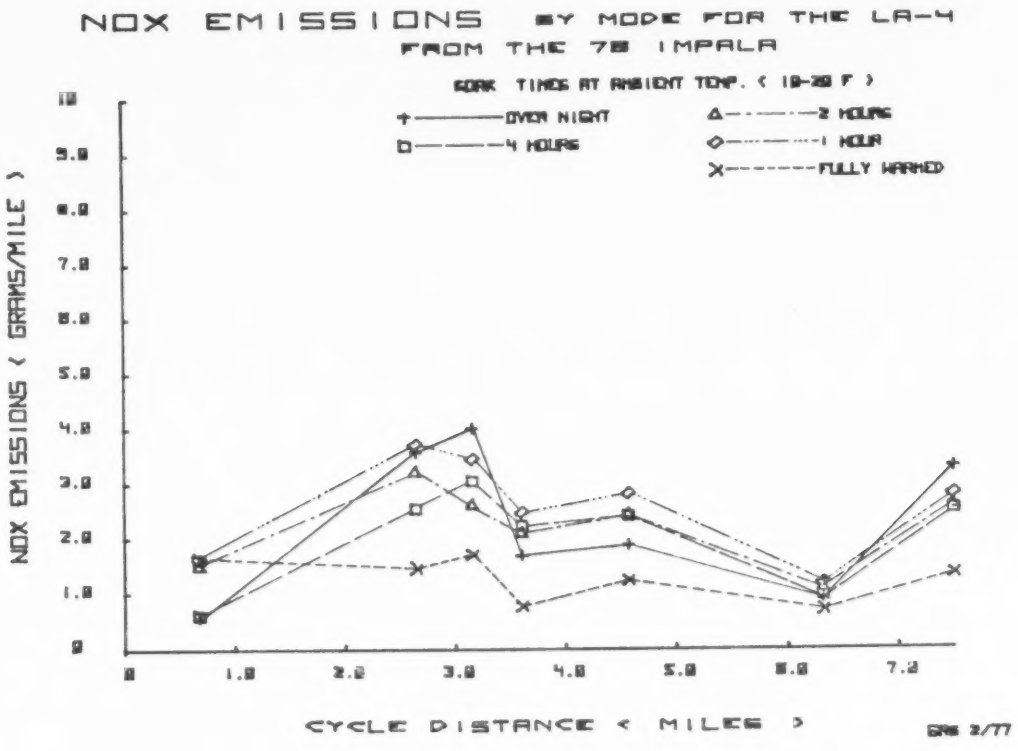

NOX EMISSIONS BY MODE FOR THE N Y C
FROM THE 70 IMPALA
SOAK TIMES AT AMBIENT TEMP. (10-20 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
ERG 2/77

Figure F-14

Appendix F



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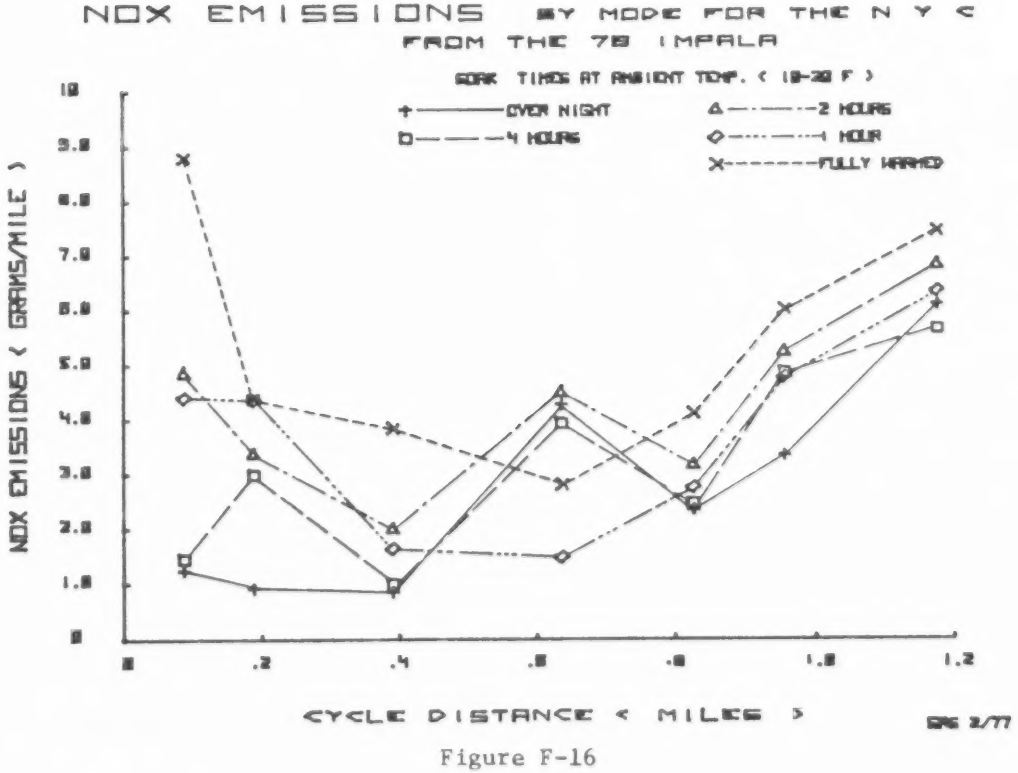
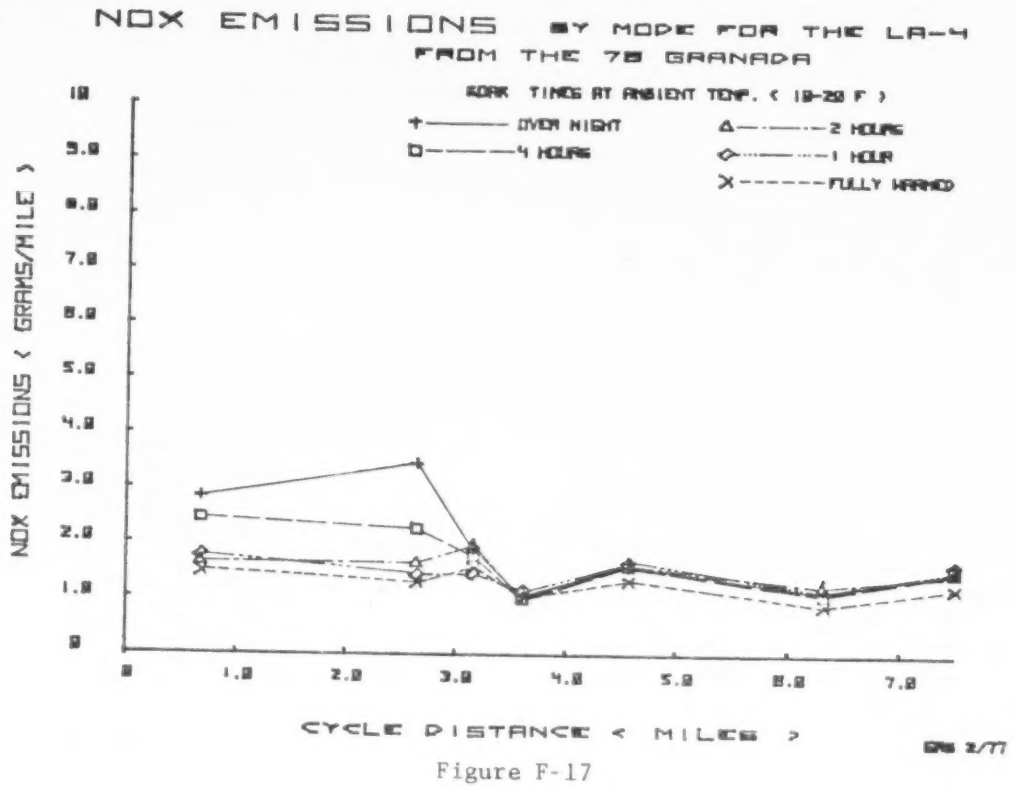

NOX EMISSIONS BY MODE FOR THE N Y C
FROM THE 78 IMPALA
SOAK TIMES AT AMBIENT TEMP. (18-28 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
EMS 2/77

Figure F-16

Appendix F



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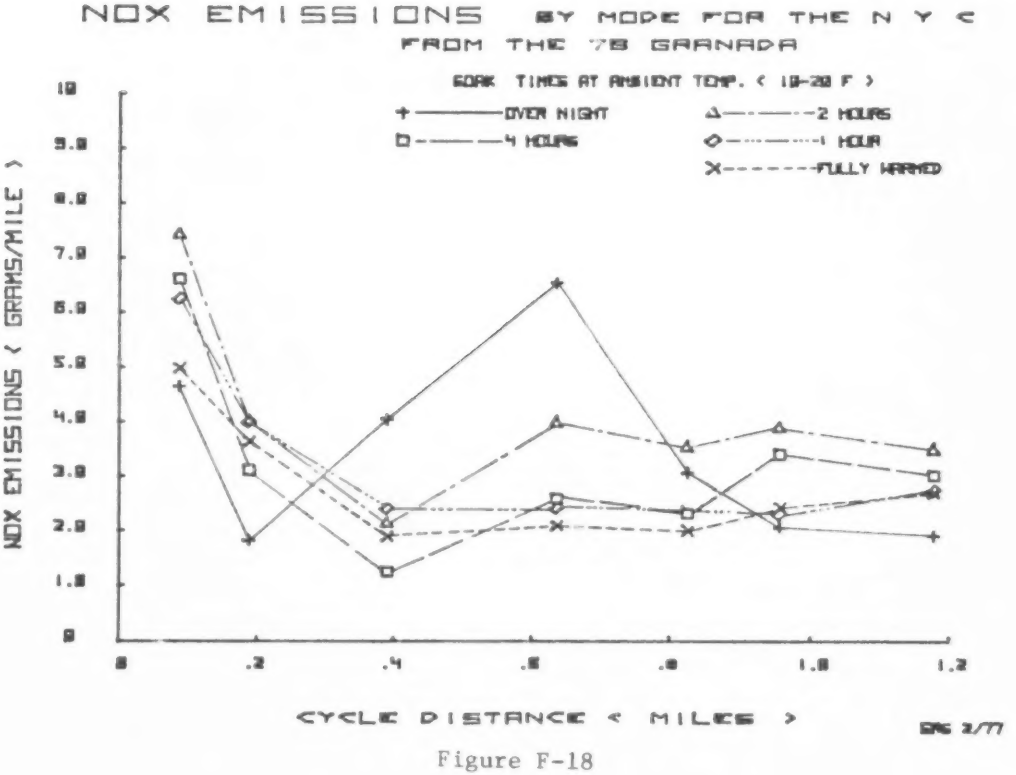
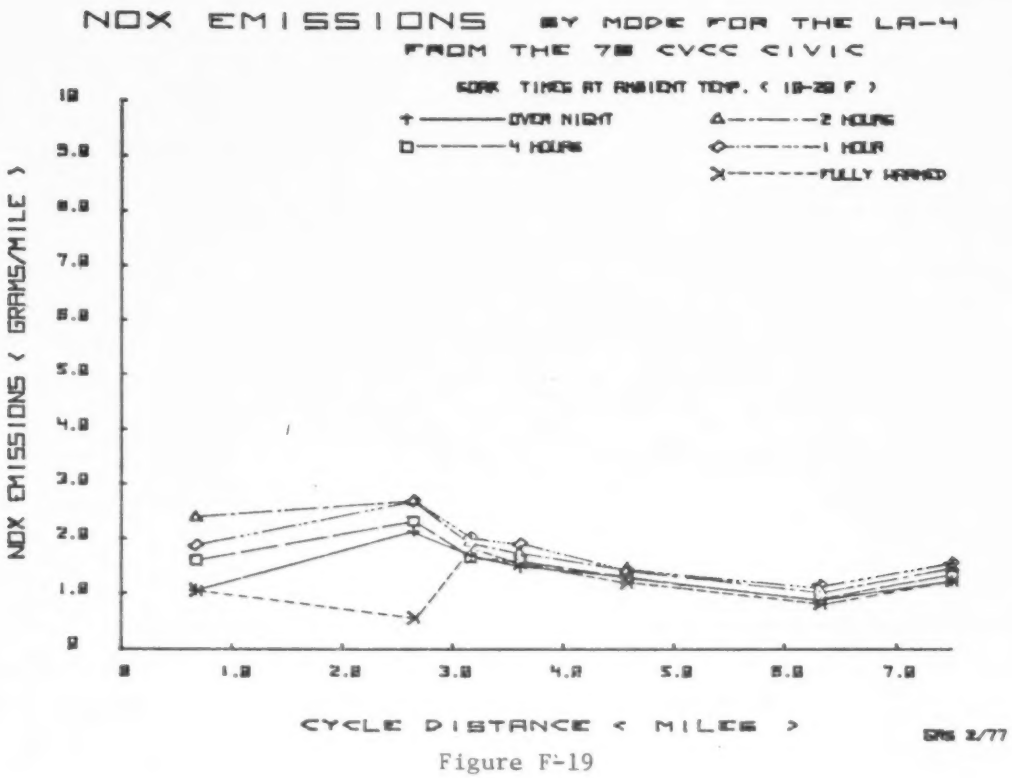

NOX EMISSIONS BY MODE FOR THE N Y C
FROM THE 78 GRANADA
SOAK TIMES AT AMBIENT TEMP. (18-28 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
DRG 2/77

Figure F-18

Appendix F



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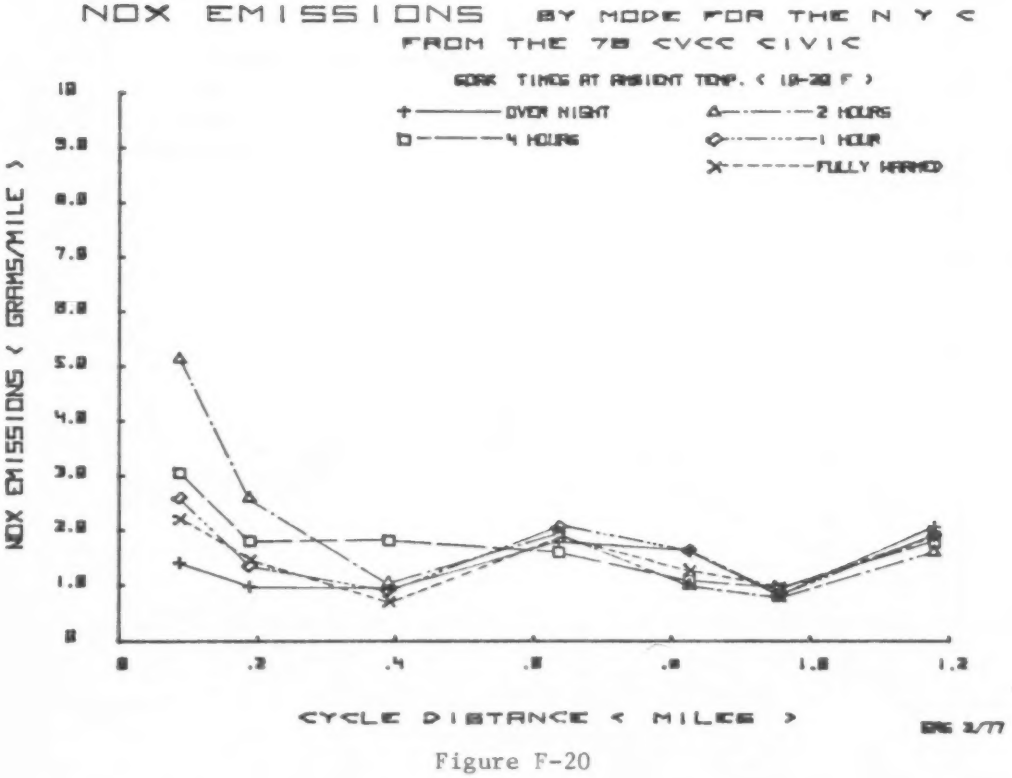
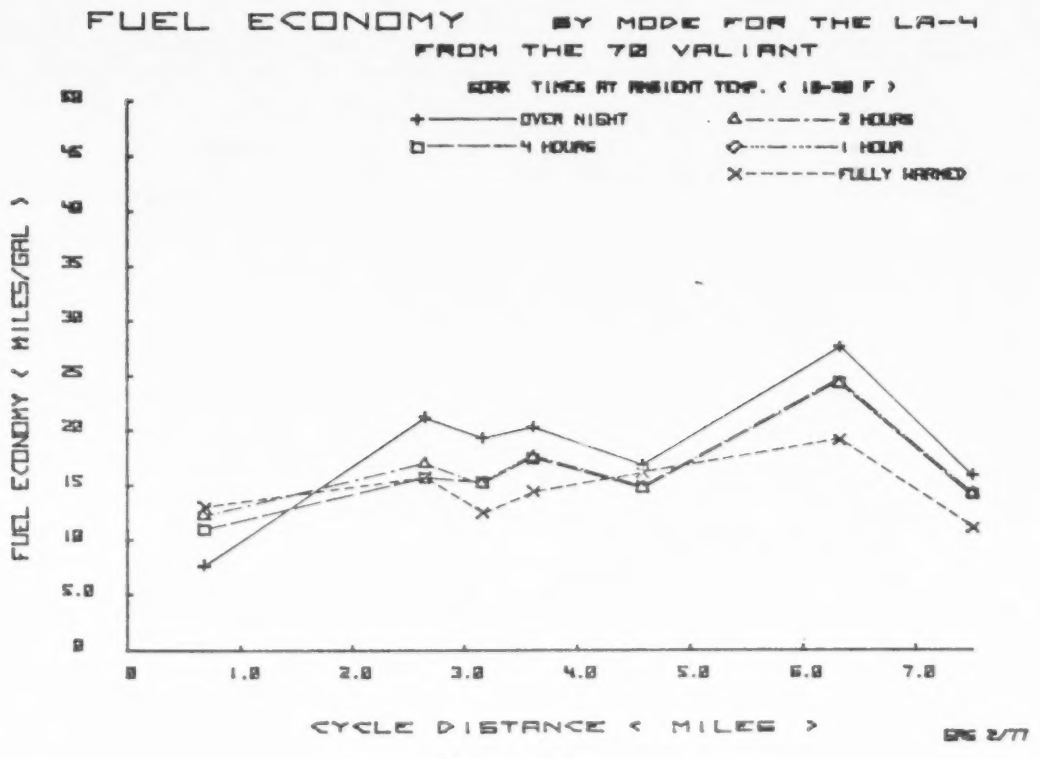

NOX EMISSIONS BY MODE FOR THE N Y C
FROM THE 78 CVCC CIVIC
SOAK TIMES AT AMBIENT TEMP. (18-28 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
NOX EMISSIONS (GRAMS/MILE)
CYCLE DISTANCE (MILES)
EPA 2/77

Figure F-20

Appendix F



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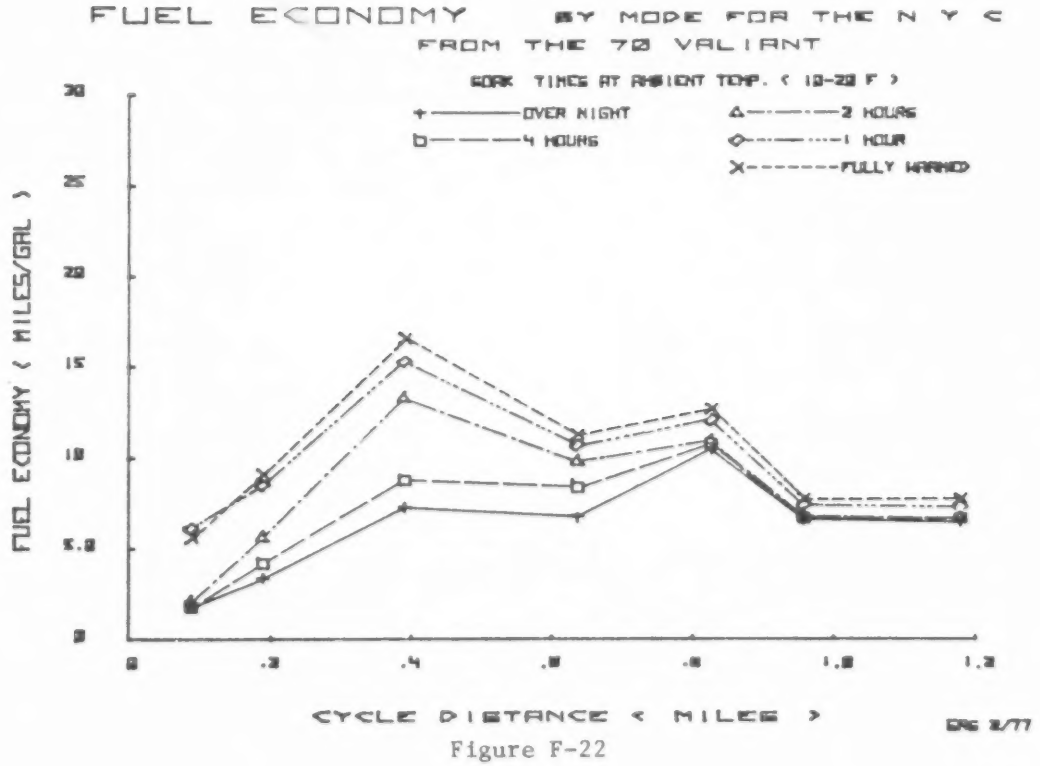
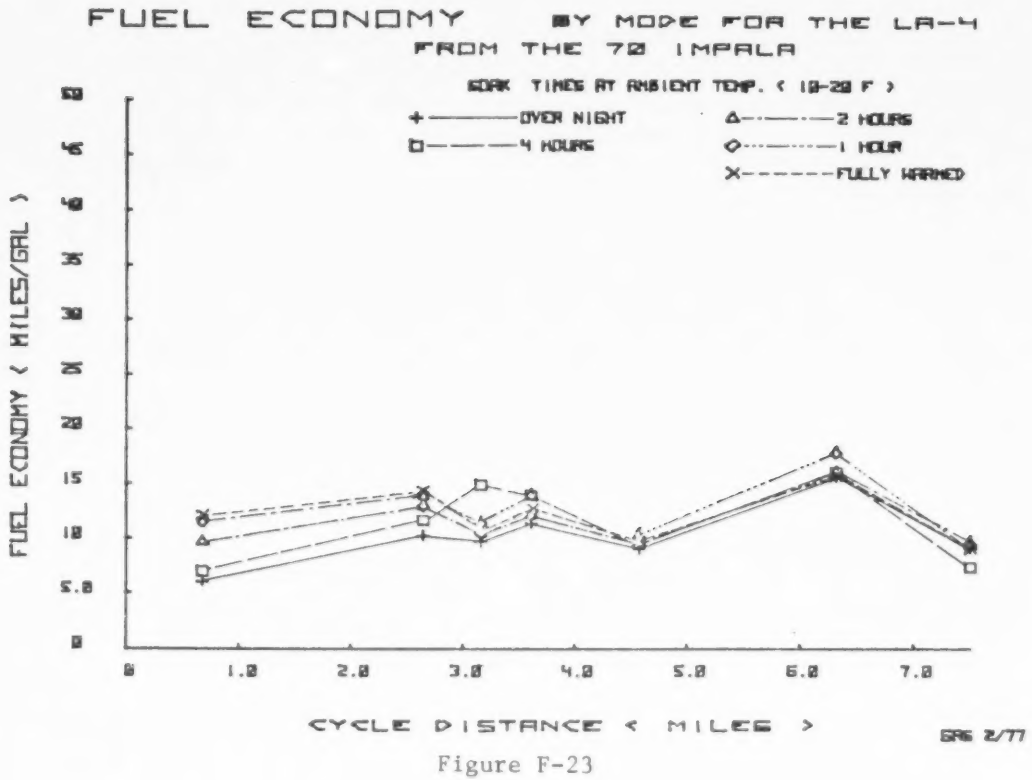

FUEL ECONOMY BY MODE FOR THE N Y C
FROM THE 72 VALIANT
SOAK TIMES AT AMBIENT TEMP. (68-86 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
EMS 2/77

Figure F-22

Appendix F



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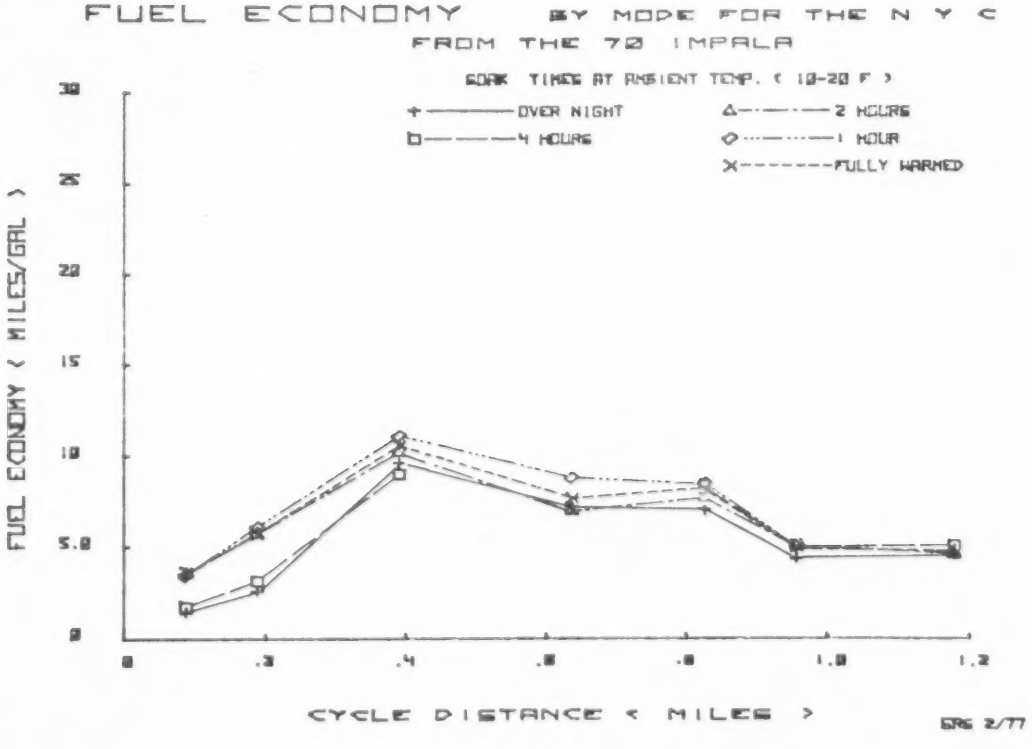

Figure F-24

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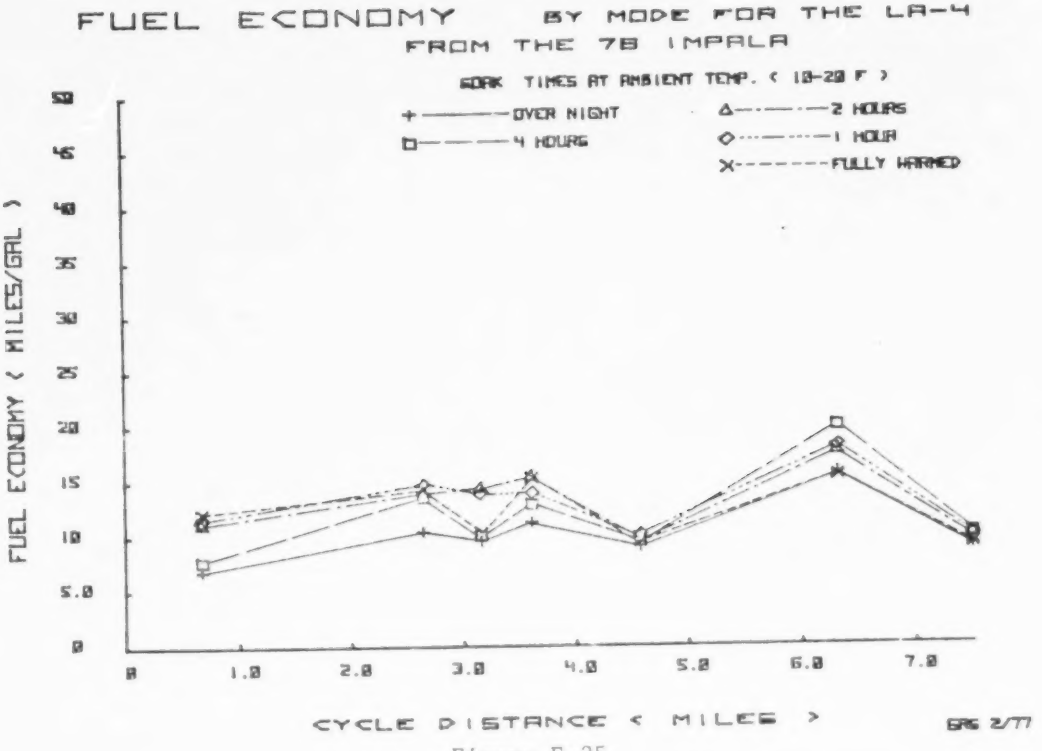

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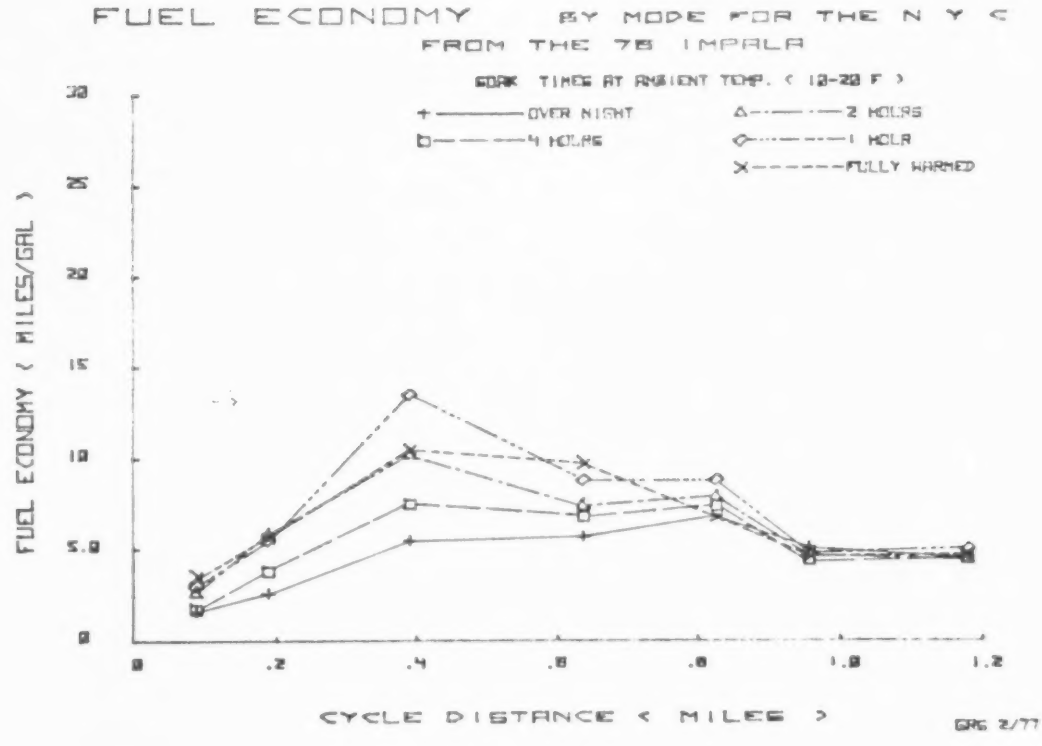

Figure F-26

Appendix F

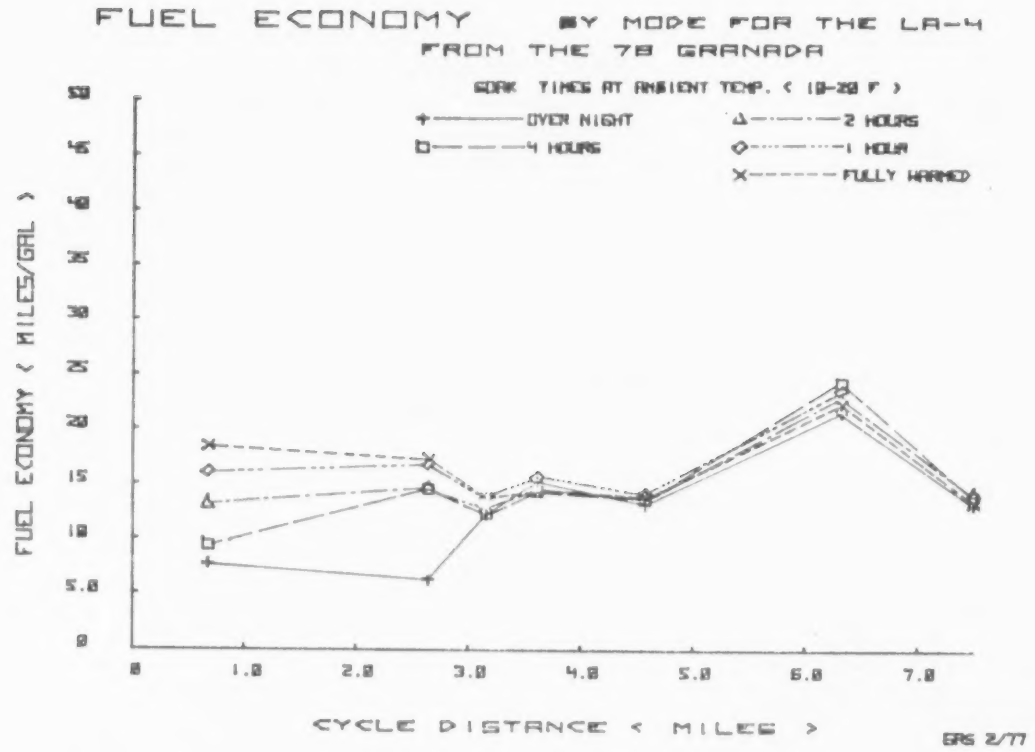

Figure F-27

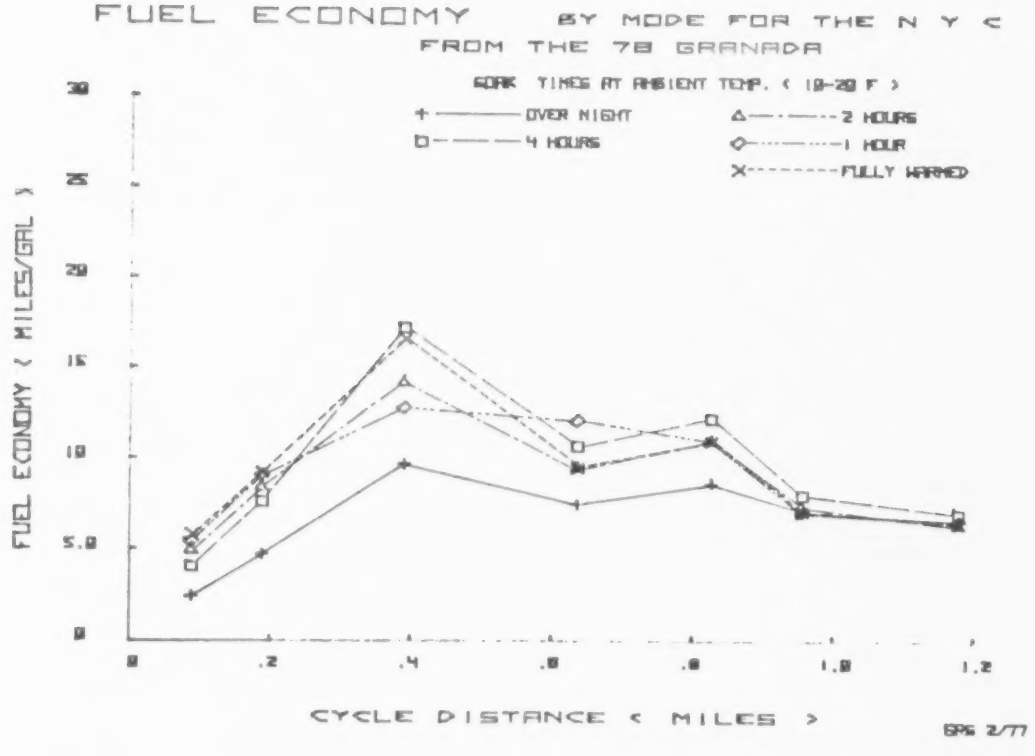
FUEL ECONOMY BY MODE FOR THE N Y C
FROM THE 78 GRANADA
SOAK TIMES AT AMBIENT TEMP. (10-20 F)
OVER NIGHT
2 HOURS
4 HOURS
1 HOUR
FULLY WARMED
FUEL ECONOMY (MILES/GAL)
CYCLE DISTANCE (MILES)
EPS 2/77

Figure F-28

Appendix F

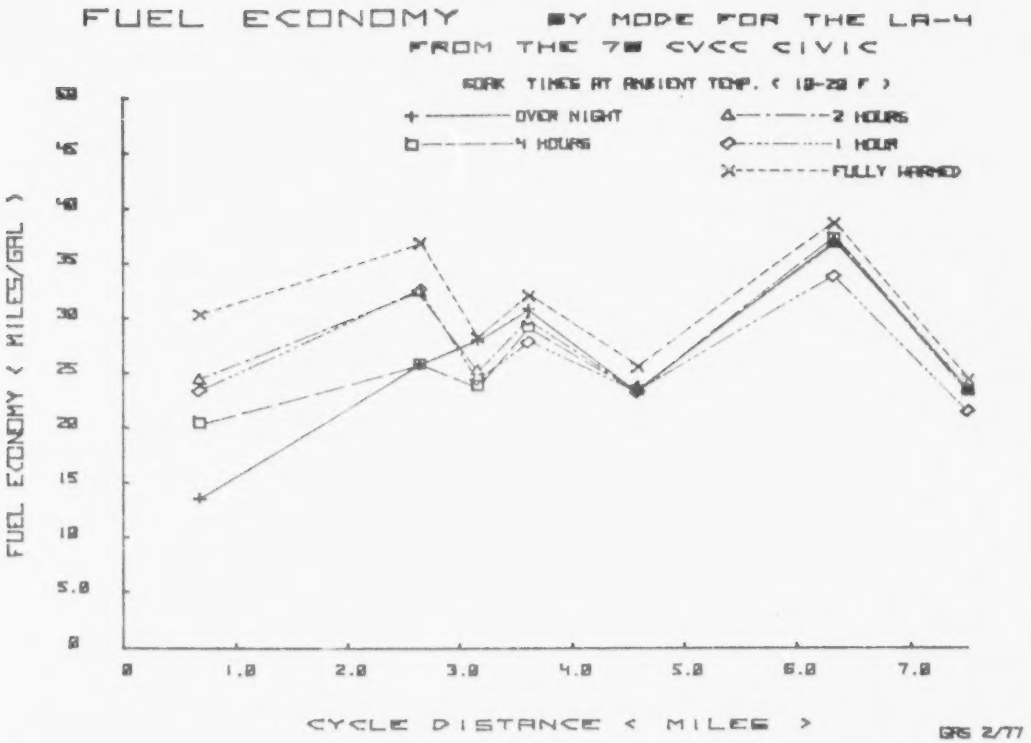

Figure F-29

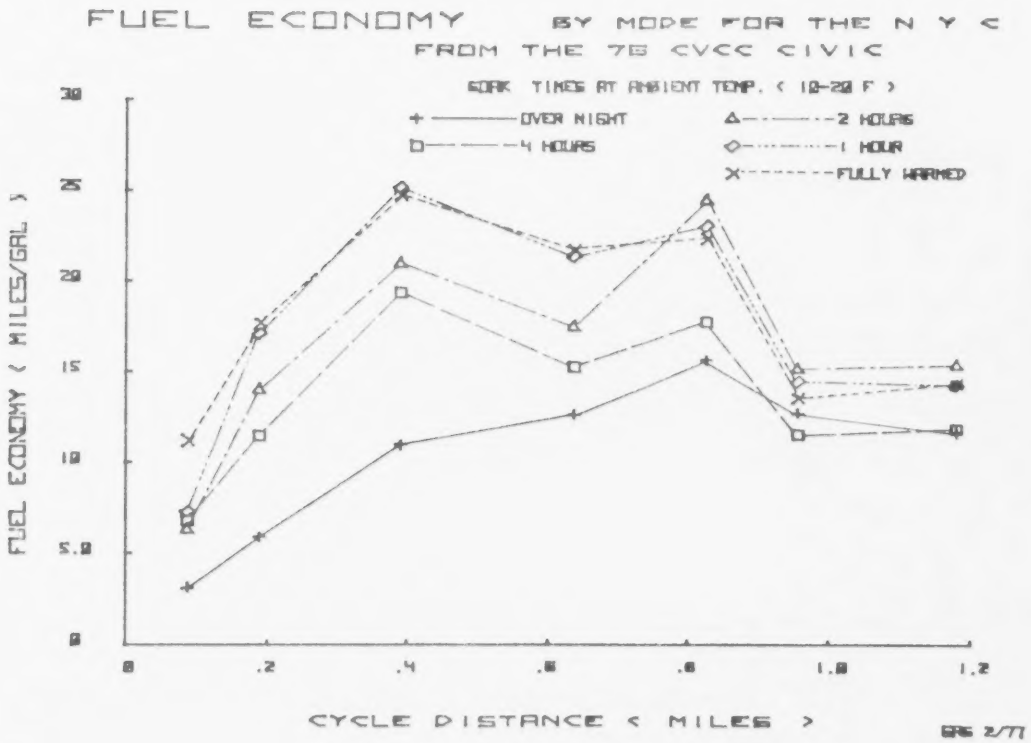

Figure F-30

APPENDIX G

Test Fuel Effects

Fuel Analysis Table G-1

The Read Vapor Pressure and Distillation curves of the two test fuels as analyzed at MVEL are shown in Table G-1.

HC Emissions

The effects on cold start HC emissions of a winter grade unleaded fuel vs. Indolene HC are discussed in the Test Fuel Effects section of the Results and Discussion.

NOx Emissions and Fuel Economy Figures G-1 and G-2

The two different test fuels produced no differences in either the NOx emissions or fuel economy.

Table G-1

Fuel Analysis

	Indolene HO	Commercial Winter grade unleaded
RVP	9.1 lb.	10.8 lb.
Distillation		
IBP	90 °F	87 °F
10%	133 °F	122 °F
50%	220 °F	215 °F
90%	322 °F	324 °F
E.P.	388 °F	380 °F

Appendix G

NOX EMISSIONS BY MODE FOR THE LA-4

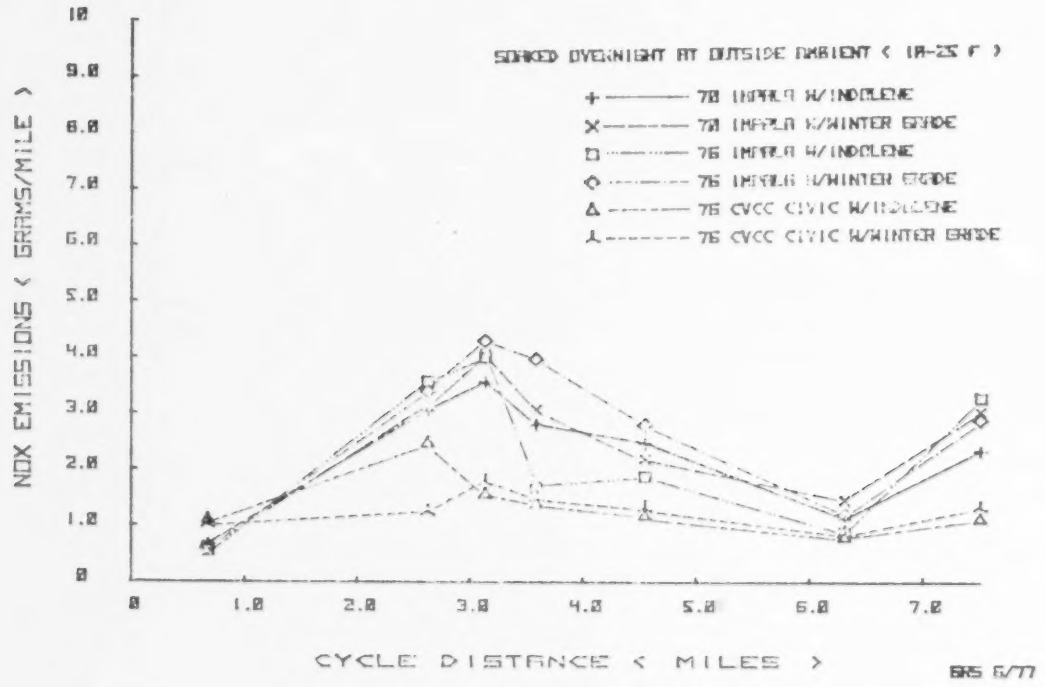

Figure G-1

FUEL ECONOMY BY MODE FOR THE LA-4

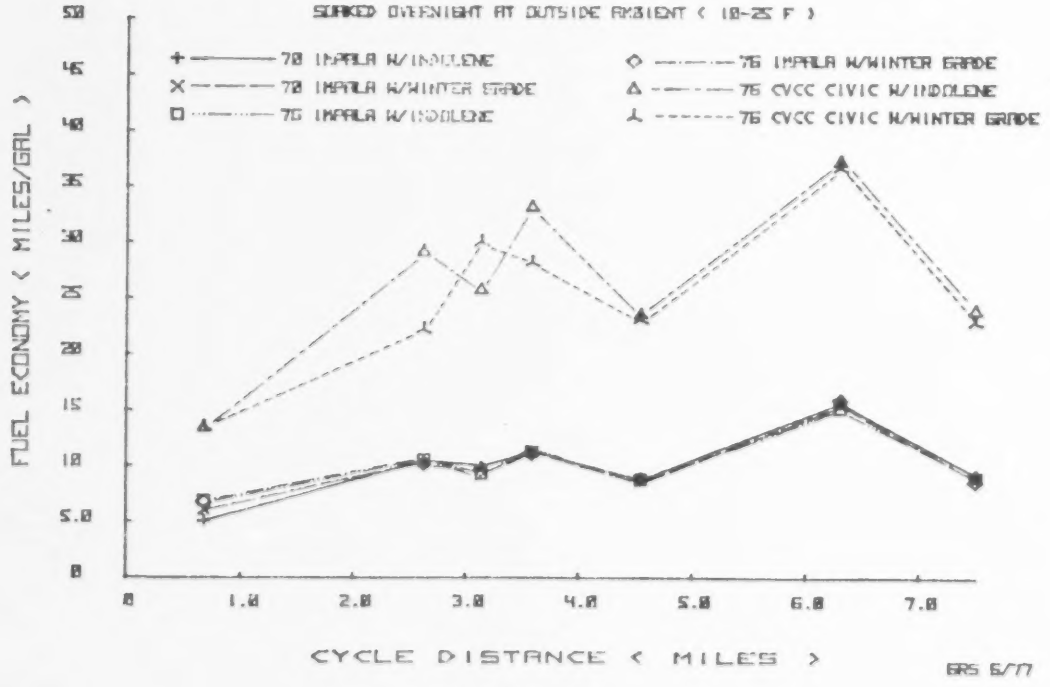

Figure G-2